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SPECIAL NUMBER

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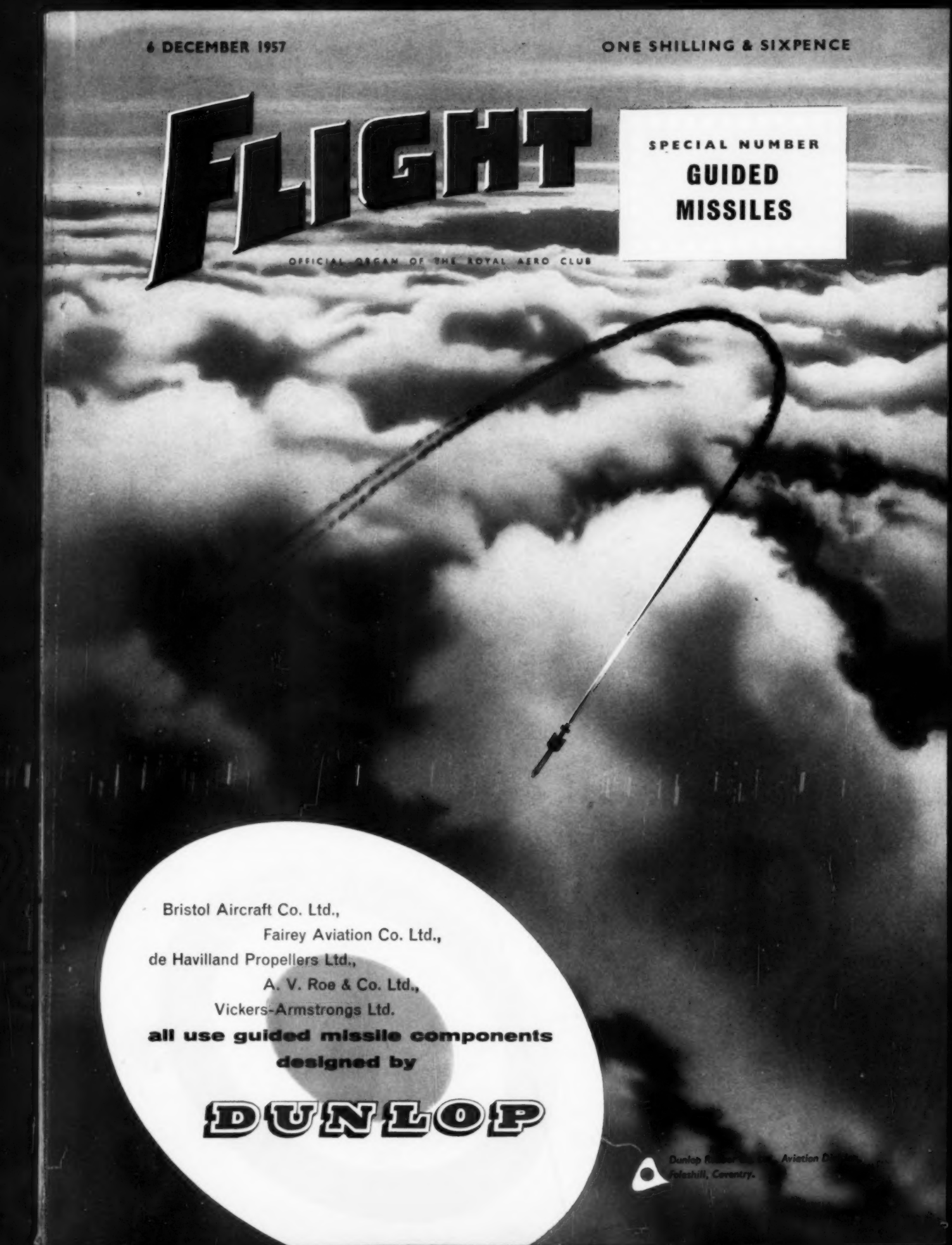

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'SERVODYNE' POWERED FLYING CONTROLS

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**HYDRAULIC EQUIPMENT.** The period between overhauls approved by the Air Registration Board for the Lockheed cut-out valve and accumulator for the Vickers Viscount is **6,000 hours**

**'SERVODYNE' POWERED FLYING CONTROLS.** The overhaul period for the Lockheed 'Servodynes', proposed by B.O.A.C. for the de Havilland 'Comet 2E' and all marks of the 'Comet 4' is **2,500 hours**

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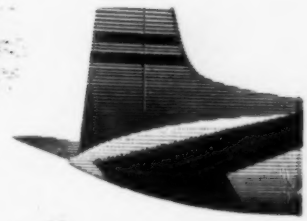

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S1371

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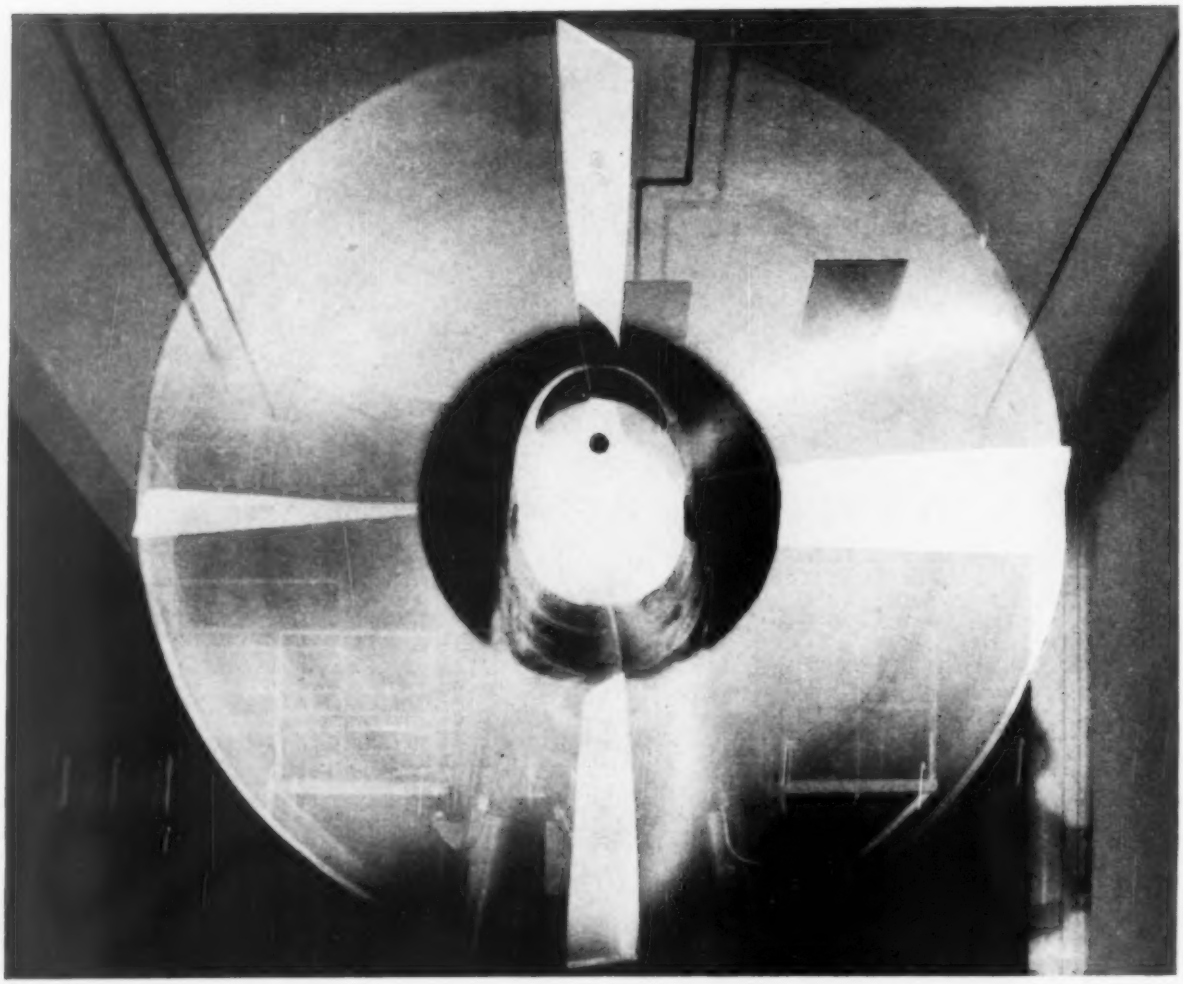
# The Matched General Motors Power Team of Allison Prop-Jet Engines and Aeroproducts Turbo-Propellers Marks Another Milestone by Receiving CAA Approval for the Commercial Jet Age

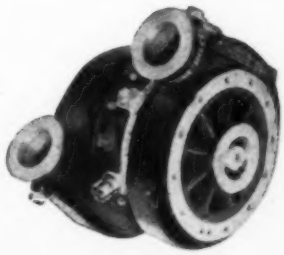


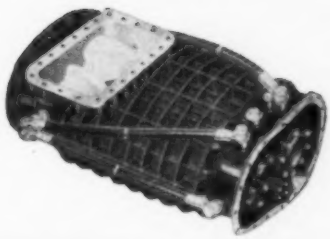
**CAA AFFIRMS DEPENDABILITY OF ALLISON PROP-JET POWER.** Another major step toward commercial airline operation of Allison Prop-Jet power in the Lockheed Electra has been accomplished with the on-schedule approval of the Allison Model 501-D13 Prop-Jet engine and Aeroproducts 606 Turbo-Propeller by the Civil Aeronautics Administration. Backing up the qualification test were 80,000 hours of development time on test stands, over 75,000 hours of experimental and service flight time and testing of engine components for an additional 50,000 hours. Approval of the CAA affirms the versatility and dependability of this matched General Motors power team for the jet age in air transportation.

ALLISON DIVISION OF GENERAL MOTORS, Indianapolis, Indiana

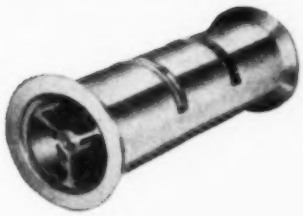
ALLISON PROP-JET POWER

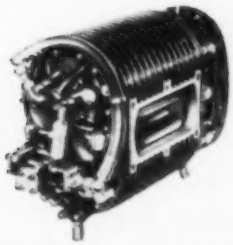
GM GENERAL MOTORS





# GODFREY — aircraft equipment





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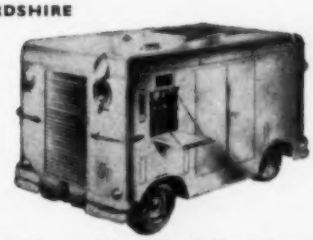

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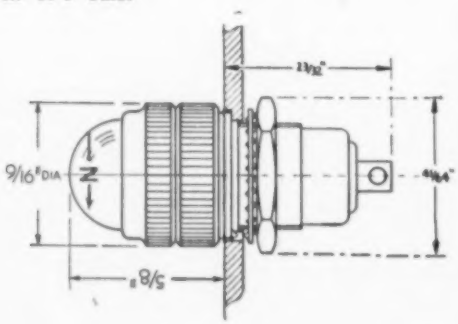
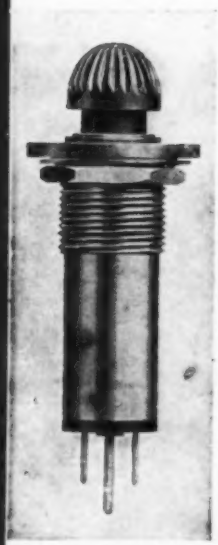


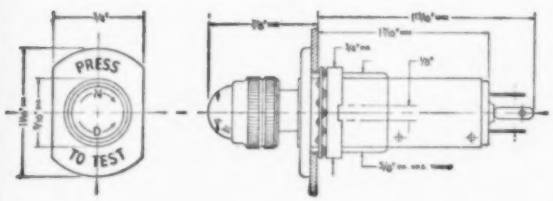

AND THE MINIATURE

# PRESS-TO-TEST

FITTING



Extreme compactness has been achieved in this new "Press to Test" component. For installation a round hole $\frac{1}{2}\frac{1}{4}$" diameter is all that is necessary in the mounting panel. The component can be extracted from either the front or from the back of the panel. There are two versions one with 3 terminals (solder or screw 1 terminal common) and the other with 5 tag terminations, solder (1 terminal common). The internal contact assembly are so arranged as to be free from normal aircraft vibration conditions and pre-determined contact pressures are maintained in the design technique. The front indicator plate can be engraved "Press to Test" or for any other engraving to suit operational requirements. The lampholder cap may be either the indicator or rotary shutter type. Colour of cap: red, green, amber, blue or clear. Can be supplied with 28V, 12V or 6V bulb.

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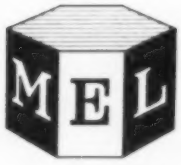


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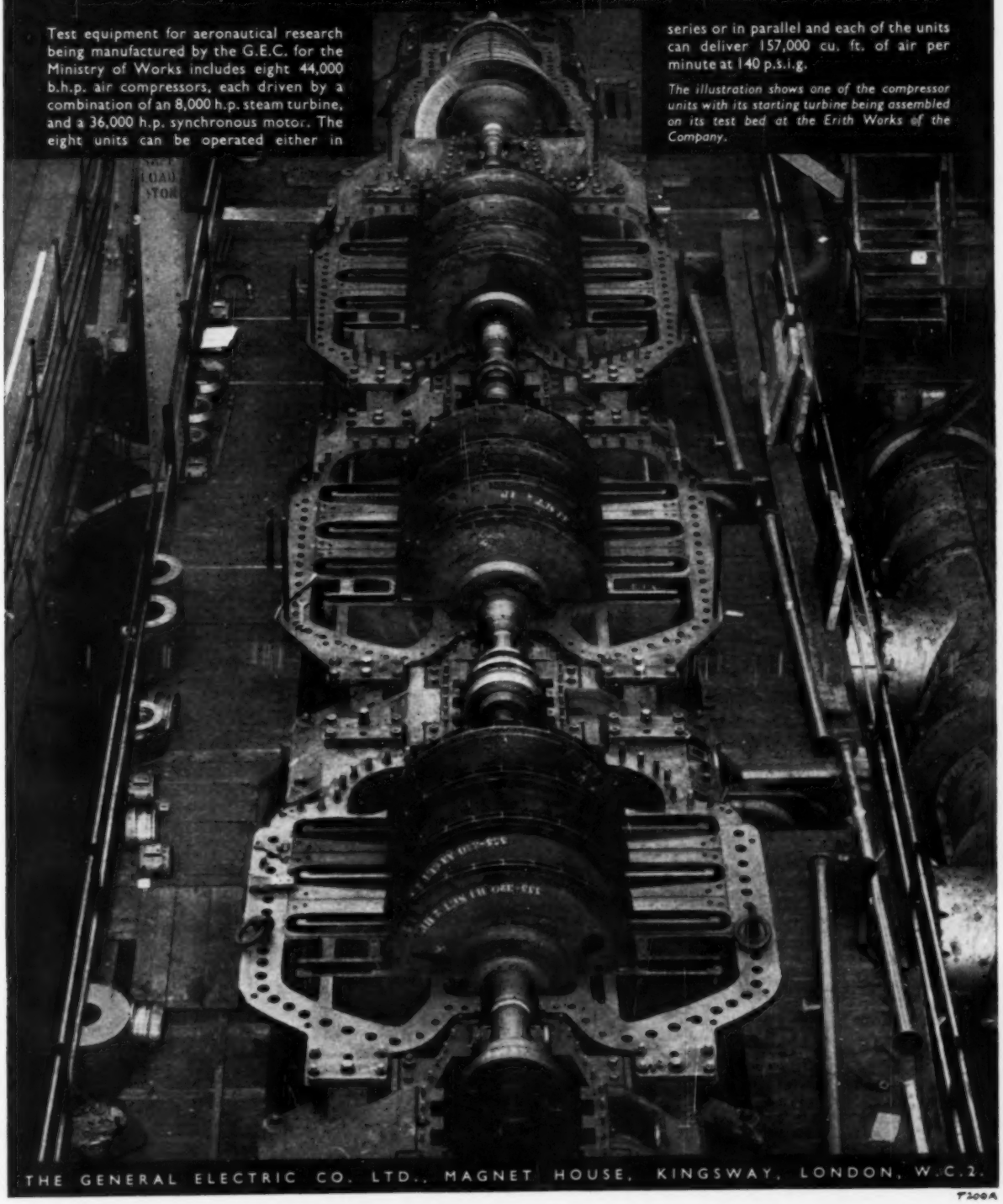
*The illustration shows one of the compressor units with its starting turbine being assembled on its test bed at the Erith Works of the Company.*



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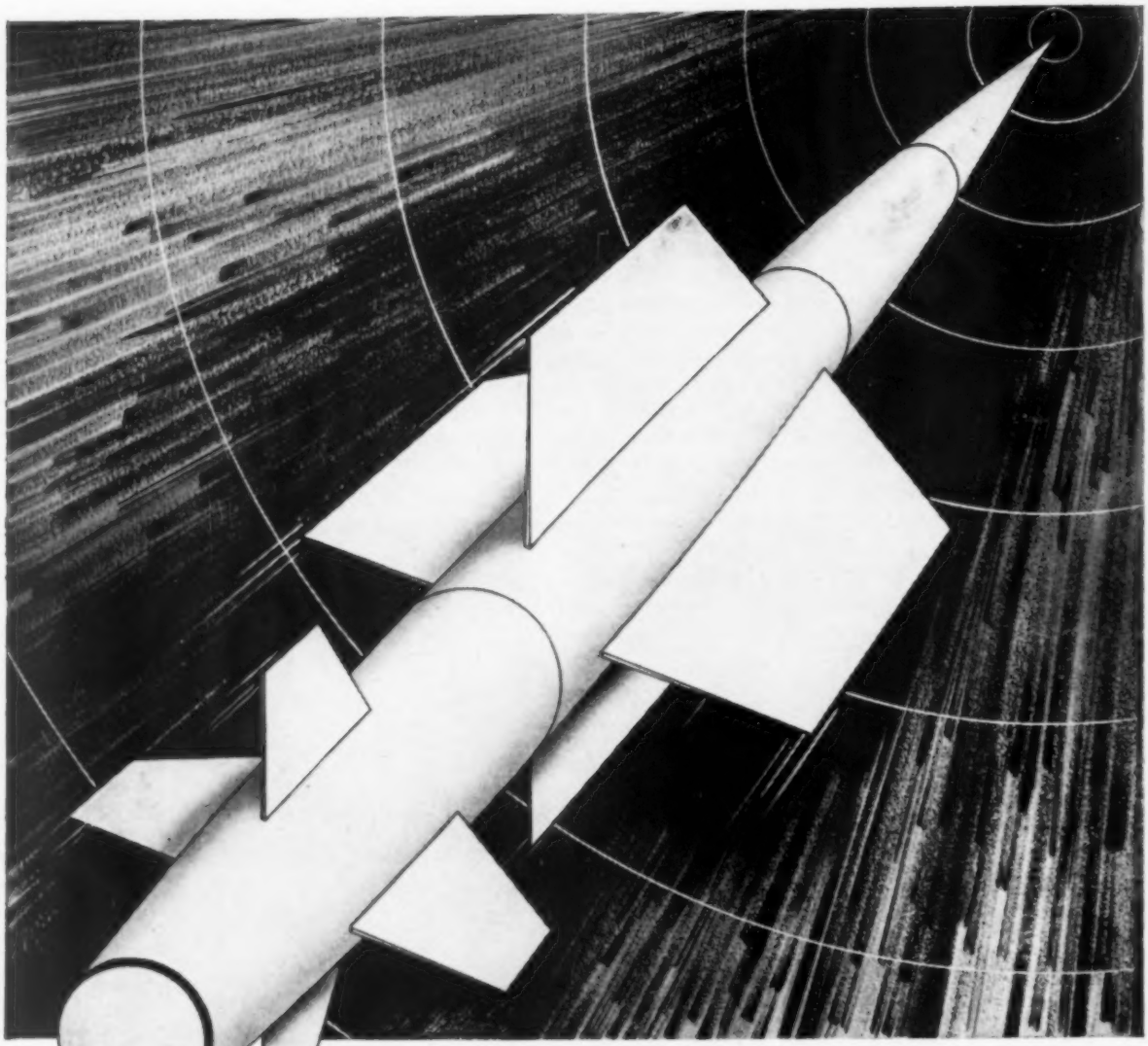

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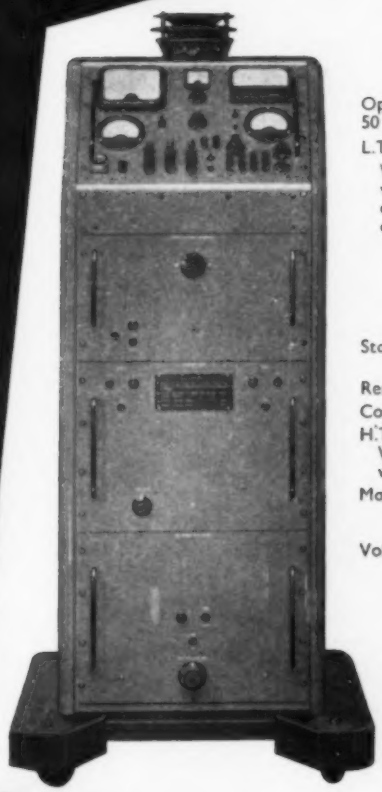

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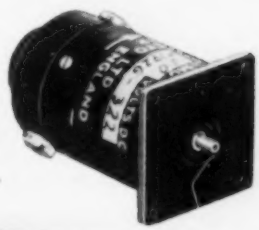

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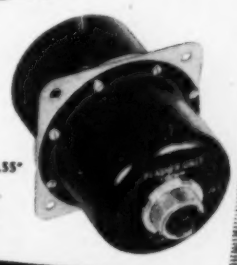

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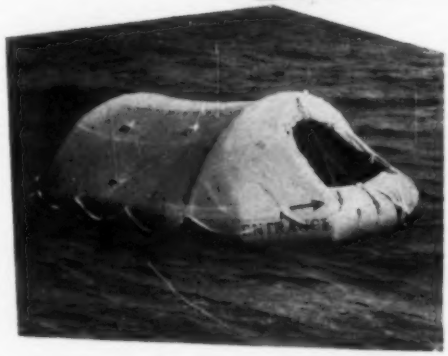

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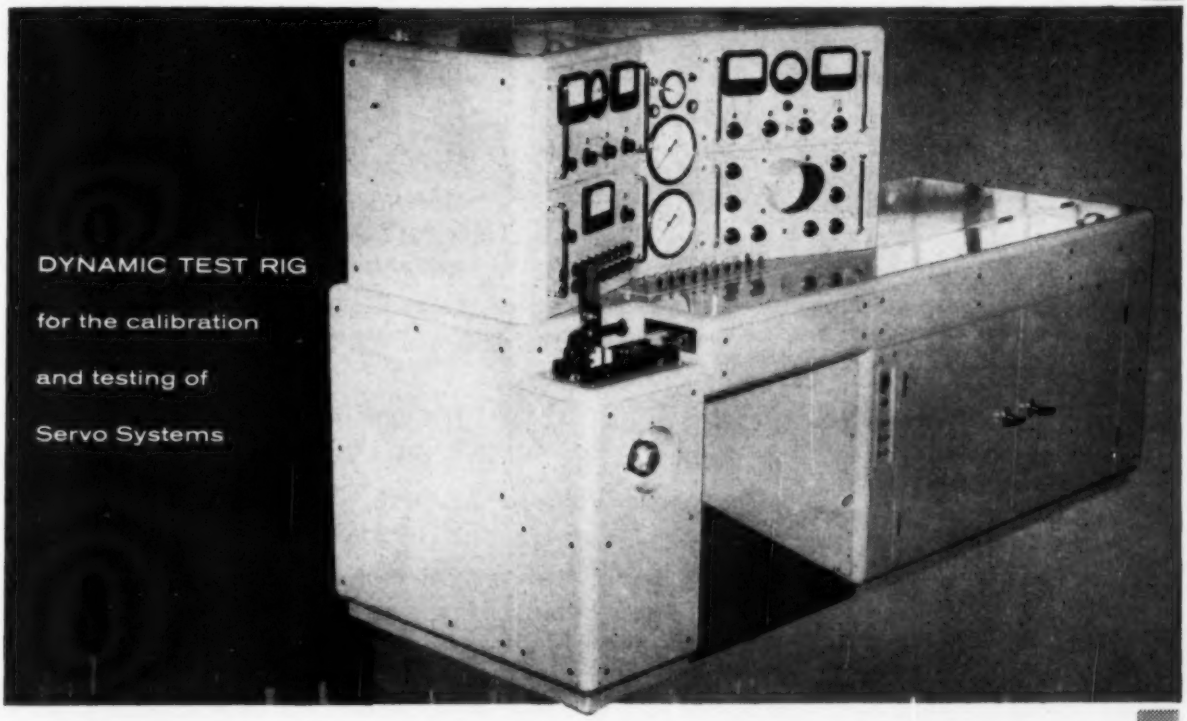


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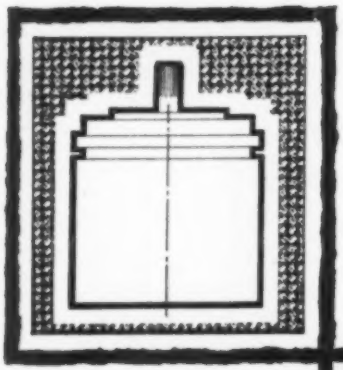
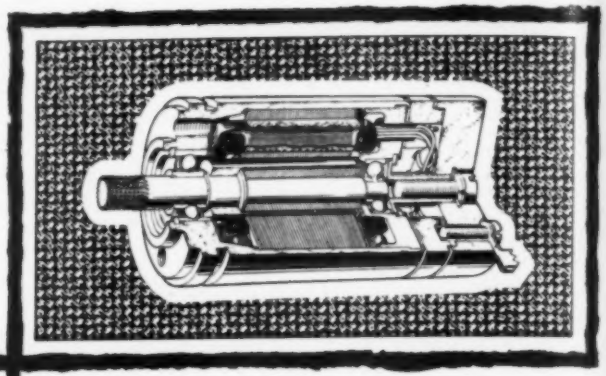
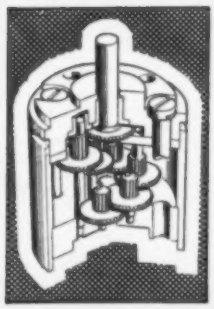


Cutaway of Size 11 a.c. Tachogenerator shows low inertia drag cup rotor, which rotates on precision, miniature ball bearings



Outline of the Size 15 servo gearhead. Widely used in instrument servo mechanisms they provide reduction ratios up to 360,000:1.

Cutaway of Size 15 servo gearhead reveals intricacy of design.



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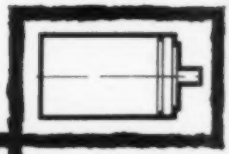
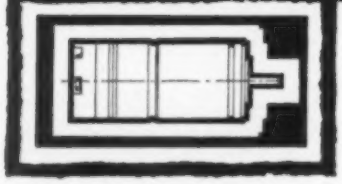
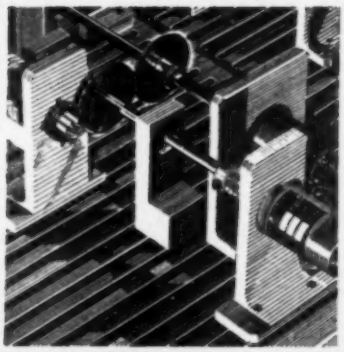
***For missiles, aircraft and automation***



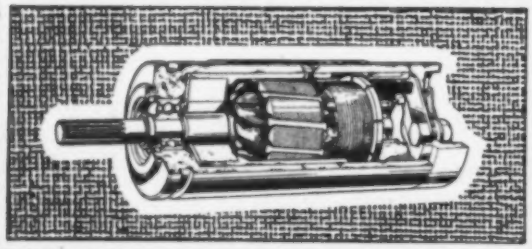
Outline of Size 07 a.c. servo motor. One of the smallest in the world.



Outline drawing of Size 11 a.c. servo motor with Magnetic Brake. Widely used in servo safety circuits for locking when servo loop is broken.



Standardised Breadboard Components, the shortcut method of fabricating servo prototypes.



Size 08 d.c. servo motor. One of the smallest d.c. servo motors, it is eminently suitable for use in compact electronic apparatus.

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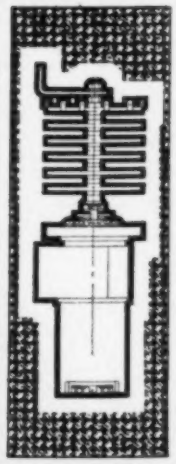

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FIRST AERONAUTICAL WEEKLY IN THE WORLD FOUNDED 1909

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# Of Genie, Wizard, Goose and Quail . . .

ASK a layman what he believes to be the latest development in guided weapons and he will probably think himself a well-informed citizen in naming the anti-missile missile. If he fancies his luck as a wag he may even suggest the anti anti-missile missile—supposing this to be the very ultimate in complication and futility. But let him beware; for he will be in danger of underestimating the lengths to which technical elaboration and low cunning are being exploited by the frantic fraternity of missilemen. That much is clear from a study of our special review this week.

To suppose that an air-to-air guided missile is a weapon that is homed or guided on to a target which it attacks on impact, or in proximity, with an H.E. charge is now to err to the point of naivety; for already in service is Genie—a device of this general description, but with the not inconsiderable variation that it has a 1.5 kiloton nuclear yield. Nor is it permissible any longer to define a surface-to-air missile as an anti-aircraft weapon, for Nike-Zeus and Wizard are coming forward in the rôle of "antis"—that being the new gibberish for anti-missile missiles. The function of these birds (again in professional parlance) is simply defined as the interception, at a safe distance from their targets, of ballistic-missile warheads approaching at three to five miles a second. And even though Senator Symington has declared "anti-missiles" (the rationalized rendering of "antis" or "anti-missile missiles") to be more than five years off, we may be sure that America's development programme has attained crash intensity in the commotion of post-Sputnik weeks.

Birds of a more exotic feather, being "counters" as distinct from "antis," are Goose—designed to decoy surface-to-air missiles—and Green Quail, which, launched from a bomber, is intended to "immunize its mother aircraft against interception." (On this interesting biological point we have the assurance of the Technical Editor.)

## . . . Polaris and Pied Piper

In the hope that a cross-heading will have enabled the reader to rally his wits sufficiently to pursue this harrowing induction, we invite his attention to Polaris, a U.S. Navy IRBM (intermediate-range ballistic missile) for operation from an NPS (nuclear-powered submarine) which is navigated by SINS (ship's inertial navigation system) as a component of the FBMS (fleet ballistic missile system). We note, with due reverence, that the strike of its nose-cone during firing trials from an EAG (experimental ordnance-testing vessel) will "probably be pin-pointed by the SOFAR bomb." It is to be deplored that no definition of this last device is available at the time of writing.

An American admiral has forecast that, armed with Polaris, the nuclear-powered submarine will become "an underwater satellite." It will, he says, be large enough to store, maintain and fire six IRBMs, and will be able to move anywhere, at any time, completely submerged. He further suggests that, in terms of deterrent value, it would compete more than favourably with land-based systems.

Reference to a satellite brings us to what must be, in this editorial at least, the ultimate missile. We allude to the U.S. Air Force's Pied Piper, described as a "reconnaissance system" and taking the form of a satellite orbiting at levels between 300 and 1,000 miles. (We must add, in justice to the missile planners of the U.S.A.F., lately in the pillory along with colleagues from other American Services and agencies, that this project dates from early last year—perhaps earlier—and that during that year a cool twelve million dollars or more was invested in the programme.)

The Pied Piper of Hamelin we remember as a remarkable fellow who really did have a way with children. But he will play second pipe to his namesake of 1960, which, we read on page 897, is to be followed in 1965 by a man-carrying version. For the idea of man following missile, when all the fairy stories have told us that missiles have succeeded men, is something that would set even a fairy piper wondering.

*FIRST OF SIXTEEN Fairey Gannets for West Germany's Naval Air Arm —a T.5 operational trainer. The other fifteen will be standard anti-submarine machines and will be delivered early next year. The order totals over £2½ million. A flight test of a Gannet by C. M. Lambert is reported on pages 861 and 862.*

# FROM ALL QUARTERS

## Unification in the Industry ?

THE future of the aircraft industry was the subject of questions in the Commons last Monday. Replying to them, Mr. Aubrey Jones, Minister of Supply, said that although the reduction in demands for military aircraft had been substantial, he was optimistic of the success of manufacturers in selling civil aircraft at present in course of production or development. He went on to say that an interdepartmental examination of the problems involved in the transition, including the future of Government policy on aeronautical research, was now in progress. The Transport Aircraft Requirements Committee was inviting the S.B.A.C. to participate in its discussions.

"Lastly," said the Minister, "it is desirable that the industry should reshape itself into stronger units. I have accordingly intimated to the industry that in placing orders for further requirements, the Government will be influenced not only by the quality of design but also by the resources, technical and financial, available to complete the project quickly and successfully; and that, in so far as these criteria were not met in isolation, the Government will require the chosen contractor to work in association with one or more other contractors."

## The Curtailment of Research

A STATEMENT issued last week by the S.B.A.C., accompanying a memorandum circulated privately to members, says that the British aircraft industry is seriously worried about the extent of the curtailment in the research and development programme and has been so ever since the Defence White Paper was issued.

The director, Mr. E. C. Bowyer, says that research and development must be maintained at a level which meets the parallel effort of competitive nations; but "little or nothing" had happened since April to mitigate anxiety.

"The Society fears that Government policy may within the next twelve months or so reduce expenditure on the research and development of aircraft and guided missiles by about one-third of its present level, but it still hopes that these cuts will not take place."

All this anxiety, added Mr. Bowyer, came at a time when the industry was having substantial export success. There was a prospect of such trade being greatly expanded; but everything depended on the continuance of an adequate research and development programme.

## Prince Philip at Aberporth

DURING a private visit last Friday to R.A.E. Aberporth the Duke of Edinburgh witnessed the firing of two Armstrong Whitworth Sea Slugs, watching from a roof-top about 150 yards distant from the launching-point. Other developments inspected by the royal visitor during a five-hour tour of the establishment included the newly erected launcher for the I.G.Y. Skylark. Afterwards Prince Philip left Aberporth for Hatfield at the controls of a Heron of the Queen's Flight.

## R-R. "Bedstead" Accident

IN an accident to the second Rolls-Royce "flying bedstead" test rig at Hucknall on November 28 the pilot W/C. H. G. F. Larsen, lost his life. The company stated that the machine, which was being used for an initial training flight, struck the gantry to which it was tethered. They added that a duplicate machine is available to continue the tests "almost immediately." W/C. Larsen, seconded from the R.A.F. to the R.A.E. Bedford, was one of a group of pilots being instructed in VTOL techniques at Hucknall.

At the inquest on W/C. Larsen, held last Monday, evidence was given that the aircraft "rose to an abnormal height" and came down on its side. A Naval pilot said that the machine had behaved quite normally during two flights which he himself had made that day.

## Honour for Dowty Director

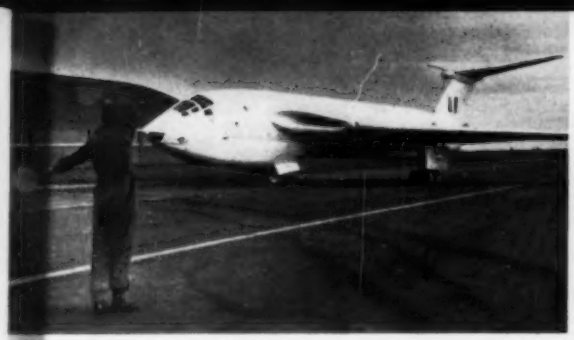
THE Simms Gold Medal of the Society of Engineers has been awarded to Mr. R. H. Bound, a Dowty Group director, in recognition of the lecture on *Hydraulics in Industry* which he delivered on November 4. On two previous occasions—for papers on *Aircraft Hydraulic Equipment* and *Liquid Springs*—Mr. Bound has received the Society's Bessemer Premium Award.

## Satellite Rocket's Descent

BRITISH and U.S. scientists stated last week-end that the carrier rocket of the first Soviet artificial Earth satellite had most probably been burned up on descending into the denser layers of the Earth's atmosphere on Sunday, December 1. The radio-astronomy station of Manchester University at Jodrell Bank, Cheshire, failed to track the rocket at any time on this date, although there were seven predicted orbits during which this would have been possible.

The last occasion on which the rocket was tracked by Jodrell

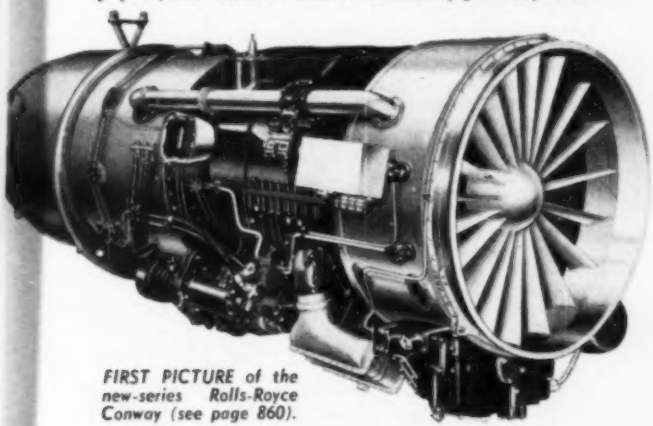
*THE WORLD'S LARGEST airliner is the Soviet Tu-114, which can carry as many as 220 passengers on internal routes. Of strikingly handsome appearance (see below), this 500 m.p.h.-plus Tupolev has three cabins, one of which is seen at far right. Typical seating capacity, respectively, is 41, 48 and 54. The pilot in the third picture is A. Yakimov. The lower deck—almost as impressive in capacity as the upper—contains galleys and freight stowage. Service lifts deliver refreshments to the upper deck.*



*FIRST VICTOR in R.A.F. service is the resplendent B.1 (serial number XA931), shown at upper left taxying in at Gaydon after delivery on November 28. Seen (right) on that occasion are, l. to r.: G/C. F. R. Bird (who has just taken over command of R.A.F. Station Gaydon); G/C. B. P. Young (former commanding officer of Gaydon); S/L. A. W. Ringer (captain); S/L. K. W. Rogers (co-pilot); S/L. P. J. Evans (navigator); F/L. J. E. Walton (bomb aimer); and F/L. H. D. Glendinning (air electronics officer). The Victor had flown from Radlett.*

Bank was its 873rd orbit on Saturday, November 30, after which it was located by U.S. tracking stations up to orbit 879. While the presumed end of the rocket's existence was linked with reports of peculiar sights in the sky above Hamburg, Berne, Los Angeles, Cowbridge (Glamorgan) and Douglas (Isle of Man), official Moscow sources said that the rocket was still in orbit.

From the U.S.A. where, as we go to press, it is expected that the first U.S. test satellite (picture, page 888) will be launched in a matter of days, it is reported that the U.S.A.F. Cambridge Research Center has projects for three 1,000 lb satellites. These are intended for orbits at heights of the order of 4,000 miles, and are said to be concerned respectively with geophysical measurements, solar physics, and "cosmic radiation and nearby planetary bodies."



*FIRST PICTURE of the new-series Rolls-Royce Conway (see page 860).*

## S/L. Duke and Fields

FROM the Hunting-Clan group of companies comes news that S/L. Neville Duke is now associated in an advisory capacity with Field Aircraft Services, Ltd., and Fieldair, Ltd. He will be concerned mainly with ferrying operations and Service liaison.

From the same source comes an interesting sidelight on the part which the ancillary industry plays in helping to raise British aviation exports to their present high levels. Field Aircraft Services have calculated that over the past four years the value of their export work represents £646 per employee.

## The Next Aircraft Generation

LAST week, in the House of Commons, the Parliamentary and Scientific Committee met to discuss problems of aircraft research and development. Among the speakers was Sir William Farren, technical director of A. V. Roe, Dr. A. E. Russell, a director and chief designer of Bristol Aircraft, and Mr. H. G. Nelson, managing director of English Electric.

Sir William Farren, declaring that "we are only at the start of what we can do in aeronautics," said that unless the resources for research that have been built up in Government establishments and industry during the past twenty years were used to the full "we should advance so slowly that we should be left behind by all our competitors."

Dr. Russell saw a danger that, unless substantial support was forthcoming to undertake the development of civil aircraft, our resources might be insufficient in quality and technical experience. Looking a few years ahead, he continued, the way was by no means clear, but an extensive investigation was proceeding, with all the major aircraft firms and the two airline corporations collaborating with the national research establishments. "In the event of a breakthrough it could be that a solution is offered not at low supersonic speeds, but at speeds in excess of Mach 2."

Summing up, Mr. Nelson said that a central agency to handle research, development and provisioning was lacking and the financing of civil aircraft on a basis similar to other competitors in a world market was uncertain.

*MULTIPLE MUFFLERS, developed by Boeing for the 707, seen fitted on two of the Pratt and Whitney J57 turbojets of the prototype. Sound-suppressor development is being paralleled by work on reverse thrust.*

## Spritely Voodooism

FOUR U.S.A.F. McDonnell Voodoos flew from Los Angeles to New York on November 27 in times claimed to be faster than the record of 3 hr 23 min set up last July 16 by Maj. John Glenn in a U.S. Navy Crusader at an average speed of 723.5 m.p.h. The first Voodoo is reported to have completed the flight in 3 hr 13 min, the second in 3 hr 10 min, the third in 3 hr 7 min 57.9 sec and the fourth—"with a supersonic burst of speed across the airfield," according to one report—in 3 hr 5 min 39.2 sec.

Two of the Voodoos then landed, but the other two returned to Los Angeles. The first completed the round trip in 7 hr 12 min 18 sec and the second in 6 hr 42 min 6.7 sec.

The Voodoos, which flew most of the time at 40,000ft, came down to 35,000ft for refuelling by Boeing KC-135s.

## Russian Atomic Aircraft Plans

LAST Sunday a 165-page book, entitled *Application of Atomic Motors in Aviation*, was published by the Russian Defence Ministry. Giving much information on Soviet plans for atomic aircraft, it claims that atomic fuel will shortly be available in quantity in Russia and that time will show the accuracy of Western estimates of 1959-1960 for the first flight of an atomic aircraft.

Two hypothetical atomic aircraft are illustrated. One is a large convertiplane, "capable of carrying an expedition from Moscow to the Antarctic in one day," with two propellers on its swept wing and one at the tail, all three rotatable to provide either lift or thrust. The other is an atomic carrier aircraft to lift a 20-ton rocket to 12.5 miles. At this height the carrier would accelerate to 1,240 m.p.h. and launch the rocket. The first stage of the rocket, using 9,900 lb of lox and hydrogen in 34 sec, would lift the assembly to 21.5 miles and then return to earth by parachute. The second stage, propelled by an atomic liquid rocket, would then rise to 183 miles and establish an orbit at 17,550 m.p.h.

## Lecture Notifications

A REVISED date and place for Mr. Handel Davies's lecture *The Weapons System Concept* is notified by R.Ae.S. Southampton Branch as we go to press; the paper will be given at 8 p.m. on Thursday, December 12, in the Institute of Education Lecture Theatre, Southampton University. As already noted, the same lecture before the Boscombe Down Branch has been postponed until Tuesday, December 17.

Another lecture notification is from the Radar Association, to whom Mr. L. H. Bedford, of English Electric, will speak on *Some Aspects of Guided Missiles* on Wednesday, December 11 (Anatomy Theatre, University College, Gower Street, London, W.C.1.).

*Portrayed here in the presence of the Duke of Edinburgh, are (l. to r.) Lord Brabazon, Sir Frederick Handley Page, Sir Geoffrey de Havilland, Claude Grahame-White and Sir Thomas Sopwith. The occasion was the Royal Aero Club dinner reported on this page.*

# The Pioneers Remember

IN all the years since the Royal Aero Club was founded in 1901 there can have been no more splendid and enjoyable occasion than that of the Dinner to the Pioneers of Aviation, held (as briefly reported last week) on November 26th. The chair was taken by H.R.H. the Duke of Edinburgh. It was a private and domestic occasion at 119 Piccadilly, for the pioneers in question —the guests of honour—are all members of the club. The 90-odd others present—all who could be accommodated—were treated to a rare selection of reminiscences and anecdotes in the course of the six brief speeches from the guests of honour, who were introduced in turn by Mr. S. Kenneth Davies, chairman of the R.Ae.C. He began by reading a telegram of good wishes from the Queen, who is patron of the club, and went on to say: "Tonight we are honouring certain outstanding pioneers, but in this room there are also many other such pioneers; some are ancient and some are modern, for in aviation we are still pioneering." To Lord Brabazon he said: "No man has given greater service to the club . . . your life gives members a human example of the object of our club." Mr. Davies expressed regret at the absence through illness of Sir Alliott Verdon Roe and Sir Oswald Short, and read messages received from them.

First to speak was Prince Philip, who remarked that the occasion reminded him of a court martial, in which the junior officer got up first. But, he said, he prided himself on his R/T discipline and brevity in the air and he saw no reason not to continue it on the ground.

On this note the chairman sat down and prepared to listen to Lord Brabazon, president of the club and the first pioneer. The dinner, said "Brab," was a high-water mark in the history of the club, which had started in a pear-drop balloon. He continued: "If there is one person in the world that we old fogies would like to see in the chair, it is the present occupant." Had Prince Philip been born when the pioneers were born, Lord Brabazon felt sure he would have worked in early aviation and would have been among the "old exhibits" at this dinner. In the course of his speech Lord Brabazon referred to the truth of his own early description of flying as being "like sitting on a blancmange in a strong draught."

Sir Geoffrey de Havilland recalled the dictum that "one doesn't *have* to be mad to build aeroplanes—but it helps." He remembered buying his first sheds from Lord Brabazon and being allowed to show his engine on Sir Frederick Handley Page's stand at an aero show in 1910 (and not being charged a penny). He also remembered seeing Claude Grahame-White trying to get out of Wormwood Scrubs! Today he thought one might attempt to build a new light aircraft and engine with £50,000-£100,000; in those days he could design an engine and two light aeroplanes for £1,000. One seldom did much stress-work; if something was not strong enough, it broke.

Sir Frederick Handley Page, the third speaker, recalled *inter alia* the early opportunities in aviation. Pioneers could not get a job in anything else; it was gaol or the aircraft industry. He mentioned "extra aerodynamical activities" by which they had since achieved fame and distinction. Speaking more seriously, he said that some thought there was nothing to be done in the future; but we should let people see that there were as great opportunities today as ever. He instanced the spirit of adventure which still attracted young people, as demonstrated by the greater keenness shown by boys for units such as the Parachute Regiment and the Commandos.

Sir Thomas Sopwith (who described himself as "the baby of the party") paid tributes to those pioneers who could not be present. He spoke affectionately of Charlie Rolls (and his balloons and cars), Frank Hedges Butler (a founder of the Aero Club), Frank McClean ("virtual founder of the R.N.A.S."), Fred Sigrist (Sir Thomas's old partner) and Harold Perrin (of the Aero Club) and he went on to speak of others with whom he had been associated, naming W. O. Manning, who with Howard Wright had been responsible for his first two aircraft, and Cecil Malone, the only surviving member of the team of the Air Department at the Admiralty. He regretted the absence, due to ill-health, of Oswald Short and recalled an order he gave to the Short brothers in 1906 to build a balloon. This was probably the first example of sub-contract in the aviation business.

At this point Sir Thomas recalled "a very silly" balloon flight he made from Battersea gasworks. A gale was blowing and he was not prepared to waste the great expense of having filled the balloon with gas. He reached a point half-way between Bristol and Bath in an hour and five minutes—an average speed of nearly 60 m.p.h.

He contrasted the procedure of today with that of the quick-starting competition on the programme of one of the early meetings. With the pilot at the wing-tip, a gun was fired and a watch started; the propeller had to be swung and the aircraft got off in nine seconds. One could not do that today.

Claude Grahame-White was the final speaker. He believed himself to be "the senior pioneer," though had Sir Alliott Verdon Roe been present he would have been two years senior. Mr. Grahame-White recalled in detail the occasion of the tragedy in which Rolls lost his life at Bournemouth in 1910, in the course of the second day's landing competition, and mentioned others—Cecil Grace and Cody—before proposing that the company should drink to "the lost pioneers."

The official part of the evening was rounded off by brief thanks from Co'onel Preston (secretary-general of the Royal Aero Club) to Prince Philip—"a younger pioneer amongst the older ones."

## CONWAY TYPE-TEST

FEW aero engines are as powerful—and possibly none as economical for high-speed flight—as the Rolls-Royce Conway. The following statement by the manufacturer is therefore given virtually in full:—

"Rolls-Royce, Ltd., announce that the Rolls-Royce Conway RCo.11 by-pass turbojet has completed a Ministry of Supply type-test in accordance with the combined U.S./U.K. schedule at a declared dry rating of 17,250 lb thrust. An official Ministry of Supply letter of approval is in course of preparation. A large part of the type-test was actually run at a substantially higher thrust figure, and at a specific fuel consumption believed to be lower than that of any type-tested military jet engine in the world.

"As previously announced, the rating of the Conway for civil airliners is 16,500 lb thrust, and the military test exceeds this by a satisfactory margin. The civil and military engines are basically the same; there are differences in features to suit individual installations. The military Conway will power the Handley Page Victor B.2.

"Last month, the Air Registration Board confirmed that the Rolls-Royce Conway had successfully completed a 150-hour test run in accordance with the combined U.S./U.K. civil type-test schedule, at a dry take-off rating of 16,500 lb thrust.

"The Conway is lighter in weight, has a lower fuel consumption and is more economic to operate than competing jet engines. Conway engines are already undergoing an intensive flight development programme. Development of the Conway continues and later versions will have more thrust and improved fuel consumption. For operators serving tropical areas, liquid injection is an optional feature for the purpose of restoring take-off thrust under high temperature conditions.

"The first military Conways are in production, and civil Conways will be delivered to Boeing and Douglas in the summer of 1958. For civil operation the Conway has been ordered by Trans-Canada Air Lines for their Douglas DC-8s and by Air India International, B.O.A.C. and Lufthansa [and Varig—Ed.] for their Boeing 707-420s. The 35 Vickers VC-10s ordered by B.O.A.C. will also be Conway-powered."

*The Gannet T.5 prototype, WN.365, the author in front and Roy Morris flying from the middle seat, seen from "Flight's" Gemini.*

# HANDLING THE GANNET T.5

## *Fairey's Twin-Turboprop Operational Trainer*

By C. M. LAMBERT

WITHOUT any doubt, the Fairey Gannet T.5 is one of the most interesting aircraft I have flown. Actual weight and performance figures are still classified, but the machine can be flown at weights approaching that of a loaded Dakota yet is very light to handle and without any aerodynamic peculiarities. At first acquaintance the controls of the two turboprop engines seem very complicated but in practice engine handling is perfectly straightforward. Above all, the approach and touch-down are remarkably simple. A carrier-type landing is generally made, flying straight on to the ground without reducing power or rounding out, the touchdown being completely cushioned by the long-stroke undercarriage.

But first a word about the engines, because these are the key to Gannet flying. In accordance with Naval requirements, each engine of the Armstrong-Siddeley Double Mamba is a constant-speeding unit. In all normal flight conditions therefore the r.p.m. of each compressor is held constant and the pitch of the propeller directly connected to it is varied to absorb the power selected by the fuel input. But it is self-evident that at low power settings propeller pitch will be extremely fine if compressor r.p.m. are to be maintained; and if protective devices were not installed the propellers would form virtually a flat disc and give not only tremendous drag but blank off the tail surfaces and reduce control almost to nothing in the event of a runaway propeller. A flight fine-pitch stop is therefore included in the propeller controls to prevent them fining off below 21 deg in flight. There comes a point (at about 130 kt) where with power off, full compressor r.p.m. can no longer be maintained; but even at the stall the r.p.m. drop is not serious.

For carrier landing it is essential to maintain compressor r.p.m. so that full power should be immediately available in case of a missed approach. The 21 deg stop is therefore automatically withdrawn when the wheels are lowered to allow the propeller to fine off further and maintain constant-speeding r.p.m. This can be overridden, if required, by a switch on the power console. The basic fine pitch stop is fixed at 6 deg, used for starting on the ground when propeller loads must be at a minimum. High propeller drag at low power and approach speeds is avoided by a flight-idle gate on the throttle quadrant. An acceleration control allows the throttles to be slammed open from the flight-idle gate, and full power follows in three to four seconds.

The high-pressure cock levers need some explaining since they do a number of jobs. Each h.p. cock lever carries a button and has three positions: "on," "off" and "feather and brake." With the lever on, fuel supply is open and the pressing of the button initiates the lighting cycle if the throttle is closed and starts the unfeathering pump. In the off position, the pressing of the button simply unfeathers the appropriate propeller. In the feather and brake position, propeller feathering begins and the pressing of the button completes feathering and applies the propeller brake. In flight the propeller is actually held still by being taken past the feathering angle and being held by the airstream against a ratchet in the reduction gear. On the ground, casual wind-milling is prevented by the brake which is released by moving the h.p. lever from the off to the on position.

Two further systems need description. A control in the propeller system senses any reverse torque load, i.e., wind-milling torque tending to drive the turbine. In case of engine failure a doll's eye on the panel flickers and the appropriate propeller will automatically be coarsened by the feathering pump to a near-feathered setting—except during ground starting, of course. This avoids the disastrous eventuality of a propeller discing on take-off. In addition, an automatic j.p.t. control ensures that limiting j.p.t. for maximum power is not exceeded (e.g., in tropical conditions) by reducing fuel input to the engine. A bell and light give warning of this; and fuel restriction can be cut out by a switch.

When this was explained to me at White Waltham by Fairey test pilot Roy Morris, with whom I flew, my mind was becoming as fogged as perhaps is that of the uninitiated reader, but we repaired to the cockpit and looked at the hardware related to all these systems. The fog rapidly cleared. With over 120 different dials and gauges, the front (pupil's) cockpit of the Gannet T.5 is well filled but not confusing. There is just enough space to hold everything without anything being out of reach. The seat is reasonably comfortable and adjustable for height, and the visibility in all directions except rearwards is remarkably good. In fact it is an excellent compromise between roominess and accessibility, and the main instrument panel is not obscured by the electrically retractable gun sight. Since a large number of submarine sightings are still made visually the visibility factor is most important and, with two forward-facing crew members and one rearward-facing, the Gannet offers complete 360 deg coverage. The almost standard blind flying panel and the majority of engine and fuel system indicators, together with several doll's eyes and warning lights, are accommodated on the main panel. Engine instruments include miniature gauges for shaft horsepower, r.p.m., oil temperature and pressure, together with a dual j.p.t. gauge, reverse torque doll's eyes, excessive j.p.t. lights, total/main tank gauge and

"Flight" photograph

*Cruising on the port engine over the Thames near Reading.*

## HANDLING THE GANNET T.5 . . .

four doll's eyes denoting fuel transfer from wing tanks to the main tank which supplies the engines. Hook and bomb door controls are grouped with hood jettison, oxygen regulator and standby hydraulic supply selector to starboard, while undercarriage, fire extinguishers, inverter selectors, flap and aileron trim indicators, hood operating plunger and hydraulic pressure indicators are on the left. Power levers, h.p. cocks, elevator and rudder trim wheels, aileron trim switch and flap lever, are grouped on and near the power console on the left. Lighting, heating and ventilating controls, hydraulic hand pump and starter buttons are on the right lateral console. The control column is of the spade-grip type carrying transmit and armament switches; and the rudder controls are organ-type pedals with a button controlling the powered-hydraulic main wheel brakes on a lateral extension outboard of each.

Access to all three cockpits is *via* a two-rung, retractable ladder and a number of well-placed hand- and foot-holds on the starboard side. A folding handle works a hydraulic pump for external canopy operation. The climb is a long one, but not difficult.

The crew wear seat-type parachutes and such protective paraphernalia as are dictated by the operating conditions. In this case Roy Morris and I wore flying suits, soft helmets, and parachutes. I was in front, he in the middle and the rear cockpit (a two-seater in the case of the Trainer) was empty. We had full tanks and, since I was not allowed to know our weight or c.g. position, I presume that these were favourably disposed. I got out my check list and started the port engine as follows:—Check flight fine pitch stop "normal" and j.p.t. control switch "warning only," starting fuel pump switch "on," throttle at "ground idle": then h.p. cock off, press relight button to fine off the propeller pitch (visually and aurally checked), l.p. cock on, h.p. cock on, and finally, press appropriate cartridge starter button. The fuel pump started, a red light showed that ignition was proceeding, the cartridge fired after two seconds and everything wound rapidly up to 8,000 r.p.m. The hood slid closed under hydraulic power which I had earlier selected.

Windmill starting the other engine, I followed a similar procedure with the live engine at full power to provide the necessary wind. The normal complement of master, instrument and services switches was selected to get things running and we were all set to taxi out. There was slight vibration, a good strong rushing noise and a healthy looking blur of propeller blades a short way in front of my windscreen. Should anything go wrong during starting the immediate action of dropping the appropriate h.p. cock to "off" would secure the engine; and if one failed to catch, the second cartridge could be fired long before it had run down to a standstill again. Both engines have two-shot cartridge starters.

I taxied using both rudder and brakes, noticing a remote thumping as the nosewheel negotiated White Waltham's tussocky grass. During several taxying runs I couldn't quite rid myself of the habit of applying asymmetric power to turn although the concentric propellers of the Double Mamba of course do not help in this way. For directional control the brakes are powerful and the wheel track is wide but, on this occasion, we found wheel adhesion considerably reduced by the soft grass. Since everything had been checked and set during starting, the actual take-off checks were in this case simply trims neutral and flaps fully down.

We lined up, opened up, released the brakes, and bored forward across the undulating surface, unstuck at about 80 kt and climbed away steeply. The noise level was very low, though I could imagine the familiar snarl that accompanies a Gannet take-off. Roy Morris demonstrated the 21 deg pitch stop working at 130 kt with throttles closed, then put down the undercarriage and showed how the turbine r.p.m. again increased to the constant-speed setting as the 21 deg stop was withdrawn. At 115 kt he slammed both throttles open and in rather less than three seconds we had full power with a goodly push in the back.

Feathering and relighting procedures in flight are as follows:—To feather, reduce power to flight idling and drop the h.p. cock to "feather and brake," whereupon the flame goes out and the propeller coarsens to a near-feathered setting. Then press the button and the propeller stops. To relight, check the throttle closed to "ground idling" (to "make" a starting microswitch), raise the h.p. cock to "on," and press the relight button. The propeller will unfeather and begin to rotate and at 2,000 r.p.m. the starting cycle is well on its way and the button can be released. At 8,000 r.p.m. the throttle is advanced to flight idle and a couple of seconds later to the desired power setting. Roy Morris proceeded to demonstrate a feathering operation to stopped propeller in seven seconds and a relight from stopped propeller to full power in eleven seconds. During the relight the reverse torque device comes into operation for a few moments and serves to prevent a too-fast engine acceleration.

I was then shown the 64-dollar false move, that is to close a throttle to the ground idle position with the 21 deg stop withdrawn when the wheels are down. The affected propeller went back to six degrees and very high drag resulted. There was little elevator control; and when both propellers are in this state a round-out for landing is theoretically impossible. But the only time at which this characteristic might become bothersome is during the approach. The Gannet would drop like a stone if the throttles were closed to the ground idling setting, but an unmistakable gate prevents this happening inadvertently, and the build-up in drag as power is reduced below 100 or 200 s.h.p. is so pronounced that hardly any pilot would persist in reducing power. In fact nearly every Gannet approach is a no-cut, no round-out, arrival.

Having demonstrated these characteristics and a landing—notwithstanding the no-cut technique the touchdown is remarkably smooth even on rough grass—Roy Morris handed over to me. I selected full flap, neutralized the trims, lined up and started to take off. There was no pronounced swing and the rudder became effective almost immediately. The Gannet bounded gracefully off the top of a sharp hump and then flew itself cleanly off. There were certainly no problems here.

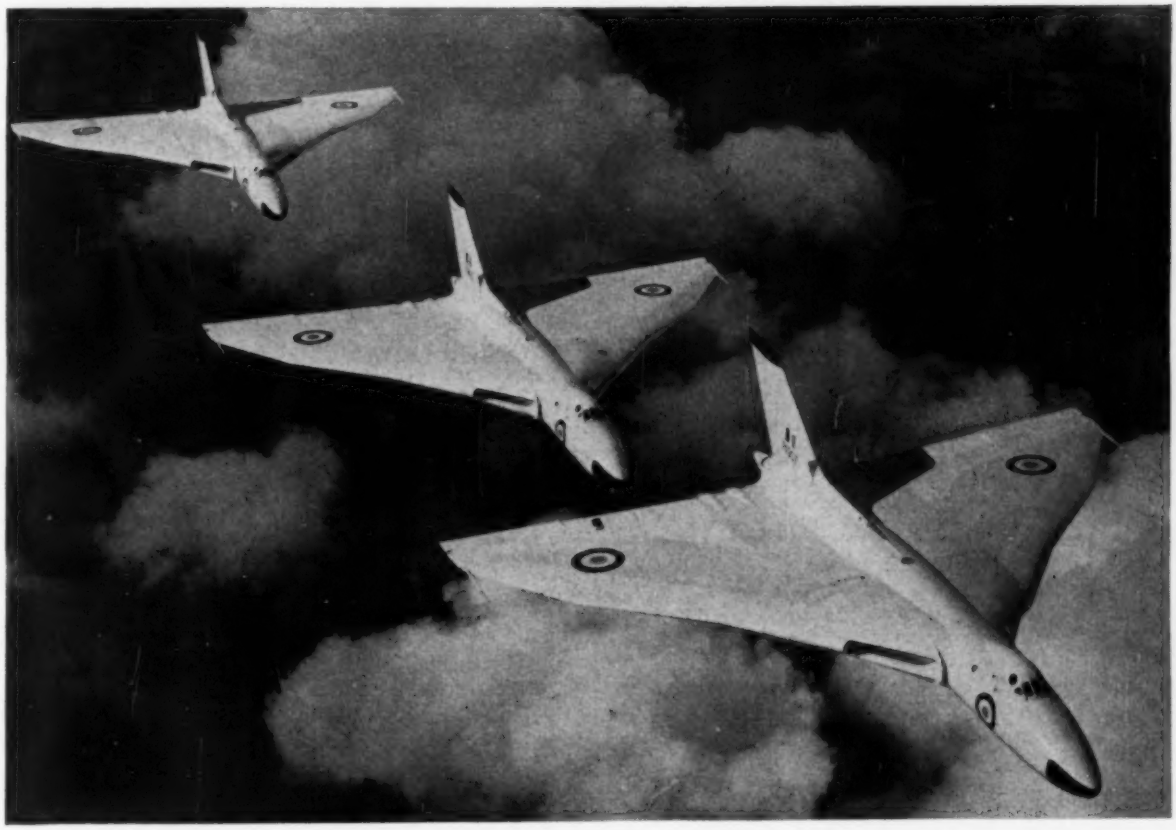
With spring tabs on all three axes, the controls have a springy and light feel characteristic of this type of tab assistance. Elevator and aileron were well harmonized and light, but the rudder was a fraction heavier and had to be fairly carefully co-ordinated to overcome the directional effects of the enormous ailerons. Lowering and retraction of the undercarriage could be felt but caused virtually no trim change. The maximum extension speed, at 175 kt, is remarkably high in relation to the aircraft maximum speed—"somewhere between 200 and 300 kt." Extension of flap caused a nose-up trim change related in severity to speed and power setting. But in no case was it excessive and only a fraction of the available trim range was required. In fact the trims appear to be designed to deal with load distribution rather than with configuration changes. Following an operational requirement which originated with a now-abandoned carrier-landing technique, a hydraulic servo changes tailplane incidence from plus two degrees to minus four degrees when the flaps come fully down. This system has been retained in all production Gannets.

I feathered and relit each engine several times and found it completely straightforward. Normal search and anti-submarine flying is in fact carried out on one engine at 130-140 kt, swapping engines at intervals; and in this condition the Gannet behaves just like any single-engined aircraft. About one division of rudder trim is needed to relieve foot loads and the Gannet is then light, quiet and very comfortable. I felt that a slight sponginess in the controls, particularly the elevator, might possibly make the Gannet waffle a little in bumpy air, but the autopilot would easily take care of this. We tried using the unit in this prototype and found it precise and quick and quite undisturbed by "swapping engines." Trainers in service do not carry the autopilot.

I tried three stalls. With the aircraft clean, pronounced tailplane buffet set in just above the stall, but ailerons remained effective and recovery was quick. Next I stalled with full flap and undercarriage and 350 horsepower on each engine. There was no warning, one or other wing tended to drop firmly but recovery was normal and immediate. One point had to be remembered. At low-power settings when the propellers were in fine pitch, elevator effectiveness was markedly reduced and greater stick travel required. This showed up particularly strongly in a "fully dirty" stall with flight idling power. I could hold the nose just above the horizon up to the stall; and a long push forward brought us into the dive for recovery. Having achieved the dive I began the pull-out with a longish pull back on the stick. At the same time I applied power, the elevator immediately "bit" and hoisted the nose sharply up. This could produce a second stall but, once experienced, allowance is easily made for the characteristic.

Finally I made a touch-and-go and a full stop landing. I used standard circuit heights and procedures and chose a fairly long straight-in approach. Flap settings are infinitely variable and I therefore "inched" them down as and when I needed more drag. A speed of 130 kt, downwind, reduced almost by itself to a 100 kt final. The Naval procedure is about 90 kt. Once "in the groove" the Gannet was completely steady and I just steamed in with the whole landing area spread out in full view ahead. Taking care never to close the throttles I made small adjustments to the glide path with power and arrived on the grass with only a firm thump to indicate the touchdown. There was absolutely no bounce and no indication of whether the nosewheel touched down before or after the main wheels. I slammed the throttles forward and went round again without any untoward trim changes. The second approach was similarly straightforward except that I had to concentrate to get clear of a slight porpoising produced by fairly pronounced variation in elevator effectiveness when I was a little over-enthusiastic with power adjustments. But again the Gannet touched down exactly where I wanted it to. I pulled the throttles back to "ground idling" to achieve some propeller drag and, as the Gannet rolled on, straight as a die, I applied brake and stopped.

Armed with a reasonable foreknowledge of turboprop characteristics anyone could fly a Gannet, even though it is a fairly heavy twin; and I personally would not mind having a stab at a carrier landing in it. Angled deck and mirror sight have already made carrier landing very much easier, but the Gannet improves even on these aids by an ease of handling and excellent visibility which are quite the best I have ever experienced in any aircraft.



# "Equal to, if not better than, any Bomber in the World"

—Mr. C. I. Orr-Ewing, Under Secretary for Air.

In announcing that the famous 617 Squadron—the Dam Busters—is to be reformed and equipped with the Avro Vulcan Delta Bomber, believed to be the fastest bomber in service anywhere, Mr. Charles Ian Orr-Ewing, Under Secretary for Air, has said that in the Vulcan "we now have a bomber aircraft which is equal to, if not better than, anything else in the world".

## "The Vulcan comes from a good stable"

In addition to Mr. Orr-Ewing's tribute, the Air Officer Commanding No. 1 Group, Bomber Command, had this to say: "We are extremely pleased with the Vulcan, both from the operating and the maintenance aspects. The way in which this large aircraft and its complex system has been brought into use in the front line of Bomber Command, without any of the enforced groundings so frequently experienced with new types of aircraft, is most gratifying. The Vulcan is giving us splendid utilization; indeed, it is far better than we experienced with any other type of aircraft, large or small. The Vulcan comes from a good stable and is liked by the servicing crews as well as the flying crews."

We are proud of our stable—from it have come: *the Avro '504'—the first long-range bomber of World War 1; the faithful Anson; the immortal Lancaster, used by the Dam Busters in World War 2; and ....now the Vulcan.*

A. V. ROE & CO. LTD. · MANCHESTER

MEMBER OF THE HAWKER SIDDELEY GROUP/PIONEER...AND WORLD LEADER IN AVIATION

# Praise from all quarters

## Admiration FROM AUSTRALIA

Butler Air Transport Ltd., NSW, have been operating Viscount 747s for nearly two years. Mr. A. Butler recently expressed 'his appreciation and admiration of these wonderful aircraft which have brought a standard of travel equal to the world's best, to the outback people we serve'.

## Growth IN THE MIDDLE EAST

Middle East Airlines report that 'The operation of Viscounts has enabled M.E.A. to achieve two aims — to build up our regional Middle East Services and to develop from a regional into an intercontinental carrier'. Up to 78% increases in passengers carried were recorded as a result of Viscount introduction, and aircraft utilisations of from 7 to 9½ hours a day were achieved throughout the summer with no serious maintenance problems.

## Praise FROM MANILA

'The Vickers Viscount is far ahead of anything I have experienced before' commented an American passenger to Philippine Air Lines. In June, on the Manila Hong-Kong route, the Viscount payload was 89.6% for the outward journey and 89.3% on the return flight.

## Satisfaction IN FRANCE

From Air France comes a report of 19% traffic increase during 1956 on the London-Paris route and a 29% increase on the Swiss routes, both served by Viscounts. Particular mention is made of Air France's satisfaction with its share of total traffic on the Viscount-operated Italian and British services.

**VICKERS VISCOUNT**

FOUR ROLLS-ROYCE DART PROPELLER-TURBINE ENGINES

VICKERS - ARMSTRONGS (AIRCRAFT) LIMITED WEYBRIDGE SURREY

TGA AT558

# CIVIL AVIATION

## DOWN WITH FARES

IN Paris and Washington are now being enacted events which will profoundly influence the future course of air transport. In Paris, whither the I.A.T.A. traffic conference repaired following the Miami deadlock, agreement had still to be reached,* as this issue of *Flight* went to press, on the form of the North Atlantic fare-structure. In Washington, the C.A.B's General Passenger Fare Investigation is now in its third week.

Unlike the C.A.B.'s hearings in Washington, I.A.T.A.'s fares deliberations in Paris are, as is customary, being conducted in the closest secrecy. The outside observer can grasp the complexity of the issues involved, but he would hesitate to predict how they will be reconciled. Most Atlantic operators must, by now, have accepted the idea of three basic fare-levels, though strong resistance from some of the smaller operators is reported. The long-term case for three classes of service would appear to be hard to accept; and the smaller airlines, with insufficient capacity to support three classes, can reasonably argue that while the thrift fares will generate more traffic—which the Atlantic routes badly need—they will also absorb most of the tourists.

Agreement on the standard of thrift austerity should by now have beeen reached on food service, though the bigger airlines wanted everything to be paid for while some of the smaller ones proposed free hot meals. It was probably easier to compromise on this than it will be on the application of cheap-rate excursion fares—which, if thrift fares are accepted, will have to be completely revised, both as to price and period of validity.

In Washington, the U.S. domestic airlines' shrill campaign for higher fares has become almost an opera *bouffé*, but, surprisingly and almost refreshingly, one airline has apparently rebelled. The present president of National Airlines, Mr. G. T. Baker, says: "When a merchant cannot move the merchandise on his shelves, he does not increase prices—he has a sale and reduces them. The airline business is in that position today. It is not selling the merchandise on its shelves. Certainly overall expenses in the airline business have increased, as they have in all other business. And we are still operating at fare levels set twenty years ago. A fare increase at this time would be most welcome, if it did not decrease our business."

***Late footnote:** Subject to government approval, I.A.T.A. have now agreed to the introduction of thrift fares across the North Atlantic, at a level 13 per cent below *present* tourist fares, accompanied by an increase in tourist and first-class fares of nine per cent. While the special immigrant fares will be retained, the 15-day excursion fare will be discontinued. Standards of service for the new third-class of traffic do not yet appear to be clearly defined: seating will be "less spacious," food service will be "simple." More specifically, free baggage allowance will be 20 kg and no liquor will be served. While at first sight these reductions do not appear to usher in an era of cheap travel, it is against the perspective of competing ocean fares that they must be considered. Tourist ocean fares across the North Atlantic are increasing steadily, and now stand at about $200 single—only $50 less than the new thrift fare. It is the narrowing gap between this figure and the cheapest air fare which will largely determine the degree to which thrift fares succeed in bolstering the growth of North Atlantic air traffic.

*Now in Santa Monica, California, for its American certification trials, Napier's Eland-Convair is seen here at Ottawa where it called on the way out from England to demonstrate its capabilities to the R.C.A.F. The trip to the U.S. West Coast was made via Prestwick, Keflavik, Goose Bay, Ottawa and Minneapolis—a total distance of 5,200 miles, flown at an average speed of 205 m.p.h. Nine Napier technicians, headed by chief test pilot Mike Randrup, were aboard.*

*Lord Douglas, chairman of B.E.A., samples the Fairey Rotodyne VTOL airliner at White Waltham. The Corporation's interest in the machine was again referred to last week by Mr. Anthony Milward, B.E.A.'s chief executive at the opening of their "Flying Business" exhibition.*

## FIRST STEPS TO MOSCOW?

AFTER a week of negotiations in London, ending on November 26, agreement has been reached on the conditions for the introduction of direct services between London and Warsaw. The discussions were held between the M.T.C.A. and a civil aviation delegation from Poland, and representatives of B.E.A. and Polskie Linie Lotnieze Lot, the Polish national airline. It was agreed in principle that services should begin "not later" than April 1 next year, and there is some likelihood that they may start a good deal earlier. At first services will be limited to one a week each in each direction, with B.E.A. using Viscount 802s and Lot Il-14s. From London Airport to Okecie airport, Warsaw, is 913 st m.

With services to Prague already in operation, interlinking of eastern and western routes is slowly becoming established. The most important service of all—between London and Moscow—still awaits political agreement. But the day may not now be far off; it is reliably reported that a Russian civil aviation delegation is expected here "in a few days' time," and it might well be that Warsaw would provide a convenient stopping point for B.E.A. Viscount services to Moscow.

## BREVITIES

LINEA AEROPOSTAL VENEZOLANA, an American source reports, have ordered six F-27 Friendships, and have taken an option on a further six. Delivery will be from November 1958.

* * *

Moscow radio reports that Aeroflot will use the Il-18 on European routes from early next year.

* * *

Mr. H. O. Houchen, director of current operations at B.O.A.C. is to resign from the Corporation at the end of the year.

* * *

The Greek Government have refused Russia permission to use Athens airport as a transit stop between Moscow and Cairo.

* * *

It is reported that an order for one Friendship has been placed by the German firm of Helmut Horten.

* * *

Installation of C-band weather radar on the final and 186th aircraft of United's fleet has just been made at San Francisco, completing a $5 million programme begun two years ago.

* * *

The records established in October by the Comet 3 between London and Khartoum at an average speed of 523.4 m.p.h. and London and Johannesburg at 433.93 m.p.h. have been confirmed by the F.A.I.

* * *

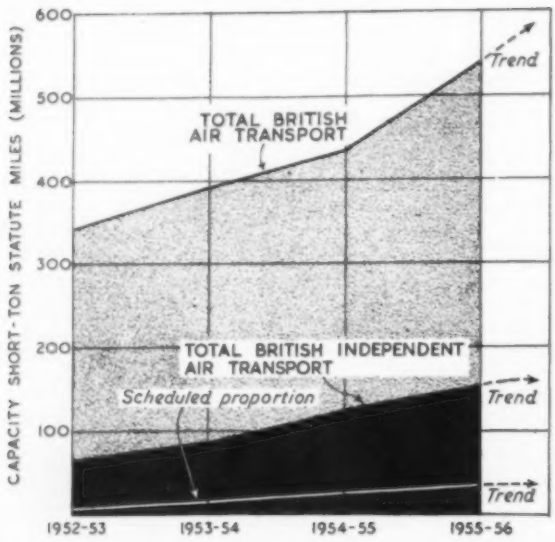
B.O.A.C. has placed an order with Kollsman for 19 air data computor units for their Comet fleet. The units are referred to as Kollsman Integrated Flight Instrument Systems, but supplement and do not replace the Smiths Flight System.

* * *

Lufthansa introduced a twice-weekly Super Constellation freight service on their North Atlantic routes on December 4. The route is Frankfurt-Shannon-New York. Other news from the German airline is that they have converted their five Convair 340s to 440s, bringing the Metropolitan fleet to nine.

* * *

The Lords are due to debate civil aviation on December 11. Lord Ogmore has tabled a motion: "To draw attention to the present situation in civil aviation; to ascertain the policy with reference to the R.A.F. Transport Command; to review the future prospect of long distance British civil airliners; and to request H.M. Government to institute an enquiry into the British aircraft industry as a whole."



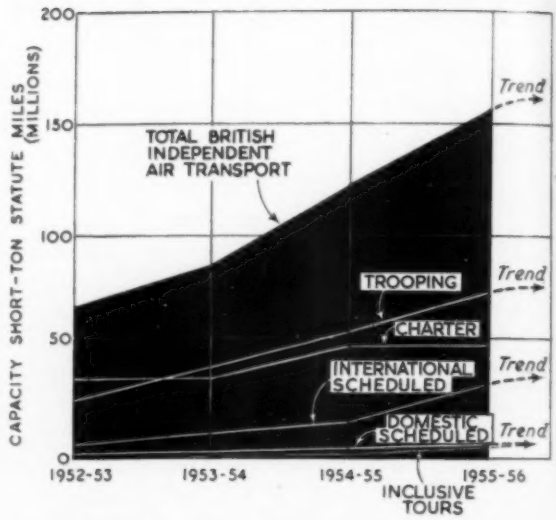
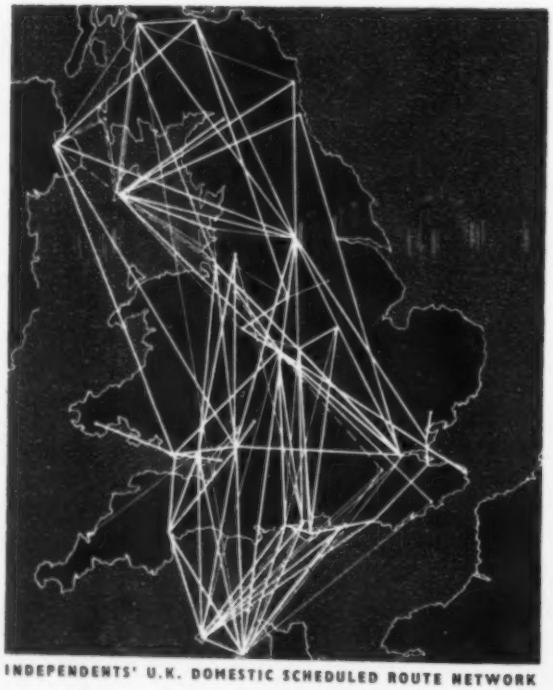




*Fig. 1, left, shows the private-enterprise share of the total British air transport effort. Fig. 2, right, shows how that share has been broken down into the various forms of business. The trend is a declining private-enterprise contribution to British air transport.*

# Cinderella Airlines

By J. M. RAMSDEN

## *A Review of Britain's Independent Air Transport Industry*



INDEPENDENTS' U.K. DOMESTIC SCHEDULED ROUTE NETWORK

*Although geographically extensive, the independents' U.K. network is not commercially intensive. By comparison, B.E.A.'s domestic network is nearly 17 times more intensively flown. Comparative loads per route-mile (1956-1957) were: B.E.A., 8,216 tons; independents, 496 tons. Heavy full lines indicate five-year approval; light full lines indicate less than five-year approval; broken lines indicate vehicle ferries. (The same annotation applies to the maps on the opposite pages.)*

**NEXT week the British Independent Air Transport Association will publish its report for 1956-1957. Last year no report was issued, as there was little new to report. Are prospects any brighter, or will the keynote of next week's report, as in other years, be "frustration"?**

THERE are about 20 members of the British Independent Air Transport Association, and in the past few years they have accounted for about 30 per cent of the total ton-mile production of the nation's air transport industry.*

As everyone knows, in 1952 the independents were given a so-called new deal by the new Conservative Government. The independents had grown up from their early post-war charter status, just as the Corporations—starting from virtually nothing—had achieved a position of strength in the international field. It was felt that some of the more restrictive terms of the 1946 Civil Aviation Act could be eased to give the independents a bigger share of the business without undermining the Corporations.

Briefly, the independents' new opportunities were: (1) the operation of U.K. domestic routes which would not "materially" divert traffic from B.E.A.; (2) the operation of international scheduled services on routes not operated by the Corporations, or to similar traffic areas; (3) the operation of Colonial coach-class services along any route (including Corporation routes), provided the service offered was of a lower class than normal scheduled services with respect to fares, stage lengths, passenger amenities and type of aircraft (the latter restriction was removed in June 1957); (4) the operation of inclusive tour or package-holiday services, provided that such services did not "materially" divert traffic from the Corporations; (5) the operation on any route of vehicle ferry services, which could also carry a limited number of incidental passengers; (6) the operation of any route from which a Corporation had withdrawn for other than temporary or seasonal reasons; and (7) the operation on any route of helicopter services.

After five years, how is the 1952 new deal working out? Is the nation, to use the slogan of that time, getting the best air

** The following companies are not members of B.I.A.T.A. and their combined results have accounted for a further two or three per cent of the independents' ton-mile production: Don Everall, East Anglian Flying Services, Independent Air Transport, Orion Airways, Starways.*

transport service from its Corporations and private-enterprise operators for the minimum cost to the taxpayer?

This is a rhetorical question, since it presupposes that there is some magic formula by which Britain's air transport industry can be made 100 per cent perfect, which there is not. It also presupposes that the criterion of perfection is minimum cost to the taxpayer, which it is not—unless the taxpayer is prepared to let the nation's air commerce go by default. The present mixture of public and private enterprise is an accomplished, immutable fact, and the aim must be to encourage and regulate its elements in the most enlightened manner to achieve the best obtainable overall results. The Corporations have been cosseted, and rightly so, in order that Britain's international air transport effort could be at a maximum. Private enterprise could not, it was considered after the war, have built up from zero an air transport industry worthy of the nation.

The independents have played the Cinderella rôle, as they have been required by law to do. But they have achieved some pretty remarkable results from the limited business ("Big Brothers' crumbs," as some of them call it) allowed to them.

We shall examine these results in some detail, to see where the independents stand today, and to assess whether past trends can be projected into the future. The aim is to give a general picture —though this necessarily involves over-simplification, and tends to depict the independents as being united in a battle *versus* the Corporations. In fact, though they are usually viewed as a whole by those who prescribe policies for British air transport's future, the independents are keenly competitive among themselves, particularly in the contest for trooping contracts, charters, and inclusive tours. But with the general picture as the aim we might first take a look at the independents' combined production effort (in terms of capacity ton-miles flown) since 1952.

Fig. 1 shows the independents' share of the total British output since 1952. This share was maintained initially, but began to fall during the last year or so. The present trend is for their share to decrease: in fact, while the total British effort went up last year, the independents' traffic—for the first time in 12 years—did not increase. Statistical evidence of this must be awaited until publication of the B.I.A.T.A. annual report on December 9: but because trooping, which accounts for nearly half the total traffic, is believed to have remained fairly static, and because published M.T.C.A. figures show declines in scheduled traffic, it is fair to guess that the independents' total traffic did not increase. It may, in fact, have decreased.

The independents must be the only air transport industry in the world whose total traffic is not expanding. One hears about the world's declining air transport profit margins, but never of the static traffic growth.

Another significant point about Fig. 1 is the small proportion of the independents' effort which is scheduled. Though this proportion has increased over the years at quite a high rate, it is still, quite clearly, a minor part of the independents' total business —less than a quarter last year (including inclusive-tours). This is significant because the proportion of scheduled activity is a measure of an air transport industry's security and stability.

The next step is to break down these outline results and fill in some details. Fig. 2 shows how the independents' business was broken down into its various elements. Clearly, by far the most effort—nearly a half—goes into Government trooping. Next comes charter work, which was the independents' original *raison d'être* and which still accounts for about a third of their business. International scheduled services are as high as they appear due largely to the vehicle-ferry services of Silver City, which generate a lot of tons, and the Colonial coach African *Safari* services performed by Airwork and Hunting-Clan, which generate a lot of miles. Clearly into proportion goes the scale of the independents' U.K. domestic scheduled services, and also their controversial inclusive-tours.

Although precise figures must abide publication of the B.I.A.T.A. annual report, Fig. 2 shows also the probable present forward trends of each kind of activity: except for U.K. domestic scheduled services and Continental inclusive tours, most forms of business are either static, if not actually on the decline.

The table on the next page shows the composition of the independents' aircraft fleets. Nearly 60 per cent of first-line capacity (small single-engined types are omitted) is provided by aircraft designed ten or more years ago. This fact will be sharply emphasized by the introduction, in little more than a year's time, of higher British airworthiness standards for older transport aeroplanes. These requirements, and their probable economic effects, were discussed in last week's *Flight*. They need not be repeated here, but they are likely to have a marked effect on the equipment plans of the independents. So far, independent orders for new aircraft have been few, as noted beneath the table. With traffic tending to be static, and—as we shall see in a moment—operating revenues apparently not yielding much return on expenditures—the financing of new equipment appears to be dependent upon finding work for the new aircraft to do. The smaller operators may continue to depend upon the

**INDEPENDENTS' INTERNATIONAL SCHEDULED ROUTE NETWORK**

*International scheduled routes (above) include normal scheduled services, mainly from the U.K. provinces; Colonial coach services; and vehicle ferries. Below, inclusive-tours have proved an effective method of getting British holidaymakers into the air. I.T. business has almost doubled itself every year since 1952.*

**INDEPENDENTS' 1957-SEASON INCLUSIVE-TOUR SERVICES**

## THE INDEPENDENTS' AIRCRAFT

| OPERATOR | DC-4 | Marathon | Viscount | Supertrader | York | Hermes | Heron | Solent | D.H.86 | Bristol 170 | D.H.84 | DC-3 | Viking | Dove | Consul | Anson | Rapide | Ambassador | Gemini |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B.I.A.T.A. members:—** | | | | | | | | | | | | | | | | | | | |
| Air Charter | 3 | | | 6 | | 4 | | | | 9 | | 5 | 7 | | 1 | | | | 1 |
| Airways Union | | | | | | | | | | | | 7 | 2 | | 1 | | 1(a) | | |
| Airwork | | | | | | 5 | | 3 | 1 | 21 | | 2 | | | 1 | | 1 | 3 | |
| B.K.S. | | 3 | | | 4 | | 2 | | | | | 2 | | | | 1 | | | |
| B.A.S. | | | 3 | | 3 | | 7 | | | 1 | | 3 | 17 | | | | | | |
| Cambrian | | | | | 3 | | 1 | | | | | 1 | 9 | | | | | | |
| Dan-Air | | | 2 | | 14 | 9 | | | | | | 4 | | 7 | 2 | | 3 | | |
| Darby | | | | | | | | | | | | 12 | | | 1 | | 1 | | |
| Eagle | | | | | | | | | | | | | | | | | | | 2 |
| Hunting-Clan | | | | | | | | | | | | | | 1 | | | | | |
| Jersey | | | | | | | | | | | | | | 5 | | | | | |
| Morton Olley | | | | | | | | | | | | | | | | | | | |
| Scottish | | | | | | | | | | | | | | | | | | | |
| Skyways | | | | | | | | | | | | | | | 1(b) | | 3 | | 2 |
| Transair | | | | | | | | | | | | | | | | | 1 | | |
| **Non-members:—** | | | | | | | | | | | | | | | | | 2 | | |
| Air Couriers | | | | | | | | | | | 2 | | | | | | 3 | | |
| Air Navigation | | | | | | | | | | 2 | | 1 | 7 | | | | 2 | | |
| Airviews | | | | | | | | | | | | | 1 | | | | 3 | | |
| Don Everall | | | | | | | | | | | | | | | | | 2 | | |
| Channel | 2 | | | | | | | | | | | 4 | | | | | | | |
| Independent | | | | | | | | | | | | | | | | | | | |
| Orion | 2 | | | | | | | | | | | | | | | | | | |
| Starways | | | | | | | | | | | | | | | | | | | |
| **Totals** | 7 | 3 | 5 | 6 | 24 | 18 | 13 | 3 | 1 | 33 | 2 | 44 | 43 | 13 | 7 | 1 | 17 | 3 | 3 |

**Notes:** Single-engined aircraft and helicopters are not shown. This table gives the independents' fleet at November, 1957. (a) D.H. Dragonfly, (b) Oxford.
**The Independents' Shopping List** : Hunting-Clan, 2 Britannia 310; Airwork, 2 Viscount 736s to be leased from Fred Olsen; Fison-Airwork, 2 Twin Pioneers; Eagle, 2 Viscount 805s; Transair, 1 Viscount 804.

## CINDERELLA AIRLINES . . .

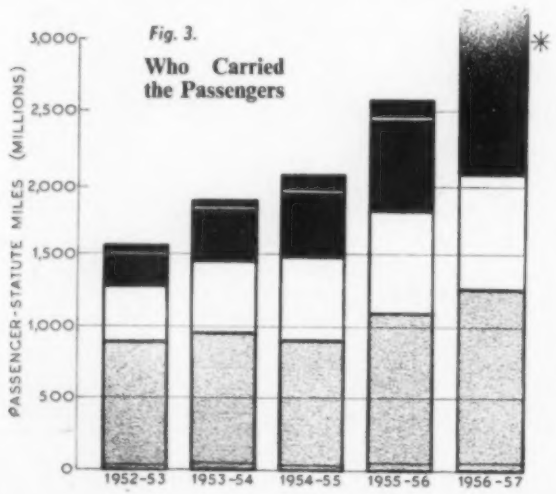
used-aircraft market, and competition is likely to be keen for the more efficient types as they come up for sale. But the dilemma with which the independents as a whole are faced—the imposition of economic penalties upon their existing equipment, and insufficient new business to justify the purchase of more than a few modern aircraft—can only, it seems, be resolved by a marked change in the conditions under which the independents operate.

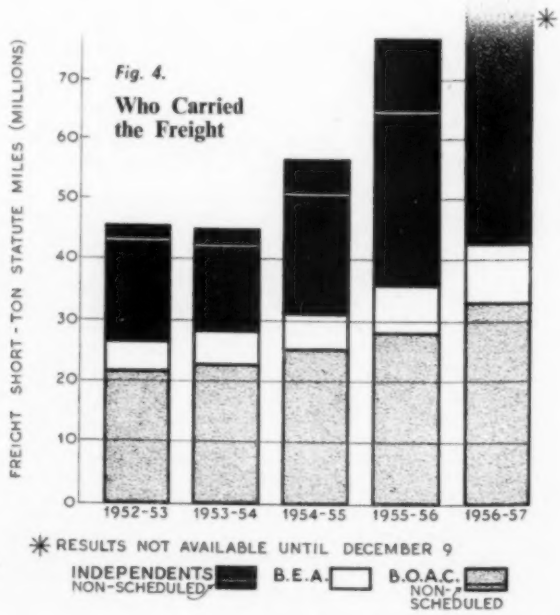
To revert to traffic for a moment, it is enlightening to break down the total ton-mile results into their two main components —passenger-miles and freight ton-miles—and to compare these over the years with the Corporations' figures. The result is shown in the chimneys in Figs. 3 and 4. The immediate impression conveyed by these pictures is that the independents have been carrying about the same number of passenger-miles as B.E.A., and nearly three times as many freight ton-miles. They have achieved this with a total employment (currently between 5,000 and 6,000) which is only half B.E.A.'s (10,000 to 11,000).

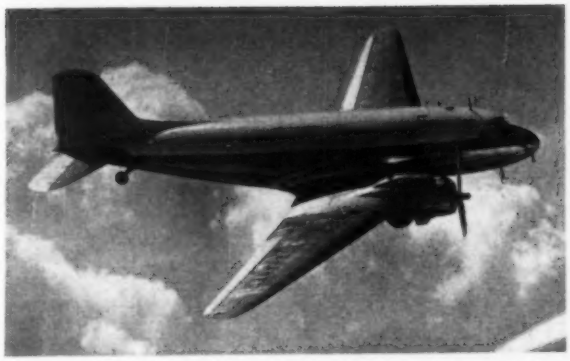
If the independents wanted to boast about their efficiency they might reasonably draw attention to this remarkable fact, but they would have to clarify it carefully by pointing out that some of their engineering work is subcontracted, and that because the bulk of their work is not scheduled (as shown by Fig. 1) they do not need the large traffic staffs, station personnel and commercial departments which an international scheduled airline like B.E.A. must have. About 6,000 of the Corporation's staff are employed in traffic and commercial departments, and at stations down the routes. But the discrepancy in employment when related to output is so large that a comparison is not unjustified. It might be added that the independents' total employment figure, when considered as a whole in this way, would be even less if adjustment were made for the duplication of staffs between one airline and another.

The maps on the previous pages show the route-networks of the independents. The impression they give is of large-scale operations; but while they do indicate that the independents' geographical scope is not so limited as people may have been led to believe, they cannot be compared with the Corporations' route-networks in terms of frequencies, traffic-densities or durations of approval.

As is well known, applications by British airlines to operate routes are approved (as shown in the maps) or rejected by the Ministry of Transport and Civil Aviation on the recommendations of the Air Transport Advisory Council. The unenviable terms of reference of this seven-man advisory body, which last year dealt with 428 applications, are "to reduce the cost of air transport to the taxpayer, and to give greater opportunities for private enterprise to take part in air transport development, with-





*The DC-3 is the oldest and most numerous type operated by the independents. Despite more stringent operating requirements in a year's time, it will be a money earner for a long time to come. The Viscount is at last established in British private air transport service: the picture shows an Airwork-operated Viscount (leased from Hunting-Clan) down the African Colonial coach "Safari" route.*

out in any way impairing the competitive strength of the Corporations' international air services."

Most independents will not concede that the "greater opportunities for private enterprise" have been created; yet there is a growing feeling in Corporation quarters that the independents have been "impairing the competitive strength" of their services. In particular, the big expansion in the independents' inclusive-tours—the cheap package-holidays on the Continent which are promoted by the travel agents—is, in B.E.A.'s view, now "materially diverting" traffic from the Corporation.

Before we quote B.E.A.'s observations on this subject it is worth recording that although inclusive-tours form a very small part of the independents' business (see Fig. 2), they have increased enormously since 1952. The average annual rate of increase has been nearly 100 per cent; last year's growth, subject to the publication of B.I.A.T.A.'s figures, was possibly more than this compared with the previous year. Inclusive-tours have really tapped the mass air travel market in a manner which has proved beyond doubt the tremendous response of the public to low fares. Unfortunately, by their very nature, I.T.s are highly seasonal, keeping the independents' aeroplanes employed for only three or four months of the year. As one independent airline's managing director puts it: "You can't justify the purchase of expensive new aircraft just for inclusive tours and seasonal work. There has to be a bread-and-butter line of business with capacity left over for some inclusive-tour jam in the season."

Small though the proportion of I.T. business is, it is really booming—to an extent which led B.E.A. to say in their 1956-1957 annual report:

"We informed the Air Transport Advisory Council in 1955 that we would not oppose applications for independent operators for inclusive-tour services at weekends during the summer months. The volume of these services to the main Continental holiday centres has, however, now grown far beyond the scale which could be regarded as economically helpful in dealing with peak traffic demands. The size of the problem is reflected by the proportion of the total summer traffic between the U.K. and the Continent carried by independent operators on inclusive-tour services. In the summer of 1956 they carried 27 per cent of the total air traffic to Spain, 15 per cent to Switzerland, 17 per cent to Northern Italy, 18 per cent to France (excluding Paris) and 21 per cent to Munich and Austria. In our view these operations have caused material diversion of traffic from B.E.A.'s services."

B.E.A. went on to refer in similar terms to certain Colonial coach services. They said: "So far as Colonial coach services to Cyprus and Gibraltar are concerned, no doubt some 'new' traffic has been generated, but we do not believe the services are 'dependent' upon it. In fact, we believe diversion of traffic from our own services has resulted."

It was unusual for B.E.A. to express these opinions publicly, because they can and do lodge such objections to the Air Transport Advisory Council, which considers, under its terms of reference, the allocation of new routes and their effect upon the Corporations. There seems to be a growing strain upon the machinery responsible for the smooth co-ordination of British air transport. Inclusive-tours have generated a new class of British traffic, most of which would not otherwise have flown. Is it being suggested that this traffic should be turned away?

But before coming to any conclusions about this, we might glance again at the independents' U.K. domestic route-network, most of which is operated in association with B.E.A. The map on the previous page shows the essentially provincial character of the routes; the heaviest inter-city traffic routes are operated by B.E.A. It is the independents who bring air transport to most of the lesser (in terms of traffic-potential) provinces, and these services are operated to the mutual advantage of both Corporation and independents. For example, B.E.A. have operating agreements with Cambrian Airways and Jersey Airlines designed to provide feeder services for the B.E.A. network. B.E.A. also have interline agreements with 17 independents, ticket interchange agreements with ten, and engineering agreements with seven.

Now B.E.A. lose heavily on their domestic routes—to the tune of nearly £1.4m last year. The success of these routes to B.E.A., and their usefulness to the community, depends, in the long-term view, upon a lowering of fares. At between 4d. and 5d. a mile, domestic air services are costlier than the competing highly-developed and increasingly-efficient surface transport; yet the Corporation, for the second time in a year (and having forecast a £1m profit for the current year) is to increase domestic fares by up to ten per cent—on some services by up to 25 per cent.

There is no authority whose duty it is publicly to challenge the sense of this. Obviously, B.E.A. do not lightly increase fares; but the impression gained by those who want to see British air services expand, and brought within reach of more people, is that short-term measures which are not in the long-term interest of the operator or the public are being too easily implemented. The same basic economic principles apply to U.K. domestic services as to international services; and it was a lowering of fares in Europe (when tourism was introduced in 1953) which put B.E.A. on a sound economic footing.

There seems to be something amiss with a system which on the one hand allows B.E.A.'s international effort to be sapped by domestic losses, but which on the other hand denies long-term commercial security to the independents. There is no escaping the fact that most domestic routes, because of their present low average traffic-densities, do not pay; if they did, there would have been independent offers to take them over. But a self-supporting domestic air transport system will not be achieved by a policy which says "If services lose, raise the fares." Such a system can only be achieved by a fares policy which promotes traffic, and by a route policy which intensifies that traffic, so that—exploited by the right aircraft—the system can be made to pay. At the moment there is no authority whose express terms of reference are to direct the nation's domestic air transport towards these ends, no executive authority whose object is to create the conditions in which the independents can, by an expansion of the existing systems of associated services, be given an opportunity to take over more domestic routes.

Such an arrangement need not undermine B.E.A.; rather would it strengthen that Corporation's international effort. It would not therefore meet the political resistance which appears inevitably to confront any other kind of independent expansion, a point to which we shall refer in our conclusions.

*Typifying the independents' biggest source of business is this Skyways Hermes 4, embarking troops (in mufti), for garrisons in the Far East.*

## CINDERELLA AIRLINES . . .

But we must first consider the really basic question—how are the independents faring financially? Though there have been numerous mergers and regroupings over the past 12 months,* there have been no liquidations, and indeed there have been two newcomers (Orion and Independent) to the ranks. Therefore, the substance of independent complaints about the low-revenue nature of their business needs to be examined.

| Type of service | 1955-56 L.T.M.s mil'ns. | Est. typ. revenue rate per L.T.M. | Total revenue |
|---|---|---|---|
| Trooping ... ... | 53.8 | 30d | £6.725m |
| Charter and contract ... ... | 35.3 | 36d | £5.300m |
| International scheduled services:— | | | |
| Colonial-coach ... | 6.1 | 45d | £1.145m |
| Normal scheduled service ... | 6.4 | 62d | £1.650m |
| Vehicle ferry ... | 4.6 | 42d | £0.805m |
| Domestic scheduled services ... ... | 3.1 | 54d | £0.700m |
| Inclusive tours ... | 2.5 | 35d | £0.365m |
| Total traffic revenue (round figures): £17 million | | | |

Whereas Fig. 2 on page 864 shows how capacities were distributed between the various types of service, the table above shows how, in the year 1955-56, those capacities were filled (they show, incidentally, an overall load factor in that year of 71 per cent). Typical estimated revenue rates per load ton-mile are shown also in the table, and these yield the approximate actual revenues earned by each type of service.

The above table does emphasize the low revenue-rates of the business. The overall figure for independents' revenue rate works out at about 36d per load ton-mile. By contrast, B.E.A.'s overall revenue rate in 1955-56 was about 64d, and B.O.A.C.'s was about 62d.

Though the table gets near to the heart of the matter, it is incomplete inasmuch that it does not indicate the profitability of each kind of work. For example, trooping may not yield much revenue per load ton-mile, but it is not so costly to operate as are, say, international scheduled services. Trooping guarantees utilization of aircraft, does not have to be "sold" in the commercial sense, does not suffer from seasonal peaks, or from fluctuating load factors, and so on.

We attempted to assess costs *versus* revenue for each kind of activity, but abandoned the attempt for want of detailed information. For obvious commercial reasons, individual firms are very secretive about their operating costs. But, as shown in the table, it appears that the independents' total revenue for 1955-56 amounted, in round figures, to about £17 million.

In order to have profited from this revenue it is apparent that the independents' costs must have been no greater than 25d per capacity ton-mile. For comparison, total operating costs per C.T.M. in 1955-56 for B.O.A.C. and B.E.A. were 38d and 41d respectively.

The independents' costs are known to be much lower than those of the Corporations. Their low station costs is a major factor behind this difference in cost levels. Another is the longer period used by the independents for the depreciation of their aircraft. Nevertheless, it would be surprising if the independents' costs were much lower than the 25d per C.T.M. we estimate. Our conclusion is that, *considered as a whole*, the independents did not show a large profit in the year reviewed. It is, in fact, more likely that they hardly broke even. Assuming that the cost figure was of the order of 30d, an actual loss of about £3 million would have been incurred.

From subsequent trends in the independents' traffic growth, and the general rise in costs, it appears almost certain that, as a whole, British private enterprise air transport is not making much money. Some firms, of course, are recording profits, but some—perhaps the majority—must be in the red.

In trying to assess exactly which companies are winning and which are losing, the researcher runs into many difficulties. No company publishes statistics as detailed as those issued by the Corporations. The majority publish no statistics whatever. The smaller companies are privately owned and have no legal obligation to provide more than the most rudimentary financial details. Only a few of the larger companies lodge their annual accounts in the files of Bush House. Most of these larger companies are substantially financed by shipping lines (British Aviation Services group by P. and O.; Skyways by Bibby Line; Airwork by Blue Star and Furness Withy; Hunting-Clan by Clan Line Steamers). Capital resources in the case of these companies are considerably greater than is shown in published accounts.

The financial picture is further obscured by the fact that many of the independent companies, in addition to the operation of air transport services, perform a diversity of other functions such as aircraft engineering, aircraft sales, pilot-training and aerial survey. But because of its financial backing, the independent section of the British air transport industry is limited not so much by lack of capital as by lack of opportunity. If the political environment was more encouraging there should be little difficulty in financing the procurement of new equipment for the exploitation of lucrative services.

We referred earlier to the political resistance which confronts independent expansions. As B.E.A. said in their 1956-57 annual report: "Competition with British independent companies presents special problems because relations between the Corporation and independent operators inevitably seem—however much one regrets it—to attract political attention."

This is the real root of the independents' problem. Last summer, for instance, the Minister accepted the A.T.A.C.'s recommendation that the independents should have a 30 per cent share of total thrift-class traffic between U.K. and Africa—the traffic which the independents, with their Colonial coach services, have pioneered. The sequel was a threatened strike by the Corporation's workers. This was the expression of something deeper than labour *versus* capitalism; it was evidence of the firmly established political structure of British air transport. So was the financial arrangement last spring between Central African Airways and B.O.A.C., on terms which Hunting-Clan, who made the first commercial bid for C.A.A., could not have afforded.

There is no doubt that any proposals to give private enterprise a bigger share of the expanding international traffic would, in the face of this evidence, appear to be quite unworkable, unless private enterprise was prepared to come to terms with the Government. The words "come to terms" mean more than a readiness (which already exists) to associate with the Corporations operationally. The independents cannot progress by hammering away at the political resistance which is the biggest bar to their progress. This has proved futile even under a Conservative Government; it would be even more futile under a Labour Government, should one take office by 1959. Nor can the independents progress by consolidations and mergers, without first creating the right political conditions for progress.

These are hard facts, and they are difficult to reconcile with the private enterprise of men who, after the war, gambled their money on a surplus aeroplane or two and went on to build efficient airlines out of hand-to-mouth charters. But they knew the terms of the Civil Aviation Act, they accepted the chosen-instrument status of the Corporations, and they have, incidentally, earned about a third of their combined revenues from Government contracts.

They now have to consider whether to compromise with the political circumstances they at first accepted, but which now constitute an *impasse* to further progress.

### CONCLUSIONS

- The independents' share of British air transport has been about 30 per cent in the past: this share is now declining, and their *total* traffic now appears to be static.
- Scheduled—i.e., secure—activities are small—about one-quarter of the total independent effort.
- Main activity, in terms of load and revenue, is trooping, followed by charter work.
- Nearly 60 per cent of the first-line aircraft capacity is more than ten years old, and will be penalized by more stringent airworthiness requirements in 12 months' time.
- Independent inclusive-tour business, though a small proportion of the overall traffic, is booming, to an extent which B.E.A. believe is diverting traffic from them.
- The machinery for co-ordinating U.K. domestic and international air transport appears to be inadequate to cope with the requirements of expansion.
- Total independent revenues in 1955-56 are estimated to be about £17 million, and their average revenue rate 36d. per L.T.M.
- Achievement of only a small profit on revenues would have required a cost level of about 25d per C.T.M., a cost which is unlikely to have been less. Hence overall profit, with increasing costs, must be small, though capital resources are large.
- The main obstacle to independent expansion, especially if a Labour Government takes office in 1959, is political: the independents have to consider whether to come to terms with the Government in order to create the right political conditions for further progress.

* *The British Aviation Services group bought the Lancashire Aircraft Corporation on December 12, 1956; Manx Airlines in August 1957; and Dragon Airways in March 1957. Airwork acquired Transair in August 1956.*

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# MISSILES 1957

**"Flight" Annual Review of the World's Guided Weapons**

*The field of missile development—for the waging of war, or in pursuance of peace—is broadening so rapidly that he who attempts to survey it must ensure that none of his information is more than a few weeks old at the most. Exactly one year ago this journal published its first appraisal of the world's missiles, a review in which the Technical Editor offered all the information that could be revealed without causing breaches of security. In the following pages, thanks to the additional facts that have become available during the past twelve months, the same writer has been able to deal with a much wider range of weapons.*

*It is remarkable that the suppositions and beliefs expressed in our previous review have without exception been supported by hard fact based on experience, and that almost all the weapons described hereafter exist as actual "hardware." Nevertheless, this does not mean that they are all fit for service; far from it. Once a weapon has been built it may take two to three years and perhaps several hundred experimental and development firings to reach the service-acceptance stage; and from there to actual employment with a "user" will probably take as long again. It follows that the drawing offices and project-study groups of the world's major guided-weapon countries have already forgotten much that is contained herein and are looking far ahead to devices that may seem fantastic even to those engaged in their development. Already the Soviet Union has shown in the past few weeks that technical accomplishment in this extremely challenging field is by no means the prerogative of the U.S.A. or even of what has become known as "the West."*

*Boost-separation of an Armstrong Whitworth Seaslug missile for the Royal Navy.*

*A few words of explanation are required before turning to the review itself, which starts overleaf. Every weapon of note of which the external appearance is publicly known is illustrated by a line drawing. These drawings are not to scale, although each is geometrically accurate. The data published beneath each is carefully qualified where doubt exists as to its authenticity, and in several cases only estimated figures are given. Boost-motor systems for launching weapons are indicated by a mechanical tint applied to the drawings—a feature which is much in evidence in the first of these drawings overleaf. This first drawing, like most depicting anti-aircraft missiles and all showing tail-standing ballistic weapons, is printed vertically.*

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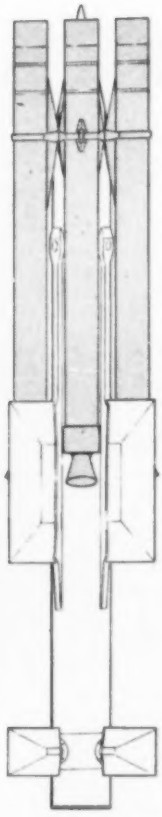
## Missiles 1957 . . .

*Interception of a Firefly target by a Seaslug surface-to-air weapon.*



**Armstrong Whitworth Seaslug** Surface-to-air. Four wrap-round boost motors, internal sustainer motor. Overall length, about 20ft; body diameter, about 16in; wing span, about 63in; control-surface span, about 63in. Weights and performance data restricted.

**ARMSTRONG WHITWORTH** As one of the principal members of the Hawker Siddeley Group, Armstrong Whitworth have for many years been the Group's principal armament company and they became involved in the development of guided weapons shortly after World War 2. The company's first task was the production of liquid-propellant rocket motors for a large number of experimental vehicles. In 1948 the company formed an Armaments Division, and when the Royal Navy decided to place a development contract for an anti-aircraft guided-weapon system earlier association with the company led them to turn to A.W.A. The resulting weapon, named Seaslug, is a large missile which, in view of its naval application, has required an exceptional amount of effort by a number of companies in order to bring it to its present near-operational state.

There have been many stages in its development, and a typical early test vehicle was exhibited at the recent S.B.A.C. Show. This vehicle was illustrated on page 330 of our August 30 issue and the internal disposition of its principal components was revealed in a sectioned drawing on page 444 of our issue of September 13.

Although of typical British configuration in having a cruciform of wings, and a second cruciform of control surfaces at the rear, Seaslug is normally indexed with all aerodynamic surfaces at the 45 deg position and the drawing shows the weapon from this angle. Both wings and controls in the test vehicle were of rectangular form, both being built up from spars and chordwise members pressed from sheet and transmitting aerodynamic loads to the main anchorages at the roots. The cylindrical body was manufactured from light alloy and the bulk of its length was carefully profiled to form integral tanks for the liquid propellants (nitric acid and methanol), which were fed by free pistons initially located near the c.g. and pumped outwards by gas pressure supplied from a generator in the nose. All propulsion system piping was contained within the body. The cantilevered rocket chamber was regeneratively cooled and provided with automatic control through a sequence of valves and solenoids.

These liquid-propellant development rounds were launched by four wrap-round boost units, each consisting of two or three motors strapped together and faired at their forward ends by pointed nose-wedges providing aerodynamic lift to swing the boosts clear at burn-out. As the contemporary GPV, Thunderbird and similar missiles employed but eight boosts, one could assume that the twelve required by the A.W.A. round conferred higher acceleration for naval purposes; alternatively the weapon itself may be heavier than its land-based counterparts. The overall boost system is exceptionally neat; unlike other British weapons, the boosts are mounted on the forebody, thus obviating the need for boost fins and presenting a particularly compact overall envelope.

In company with other weapons, Seaslug has now reverted to an I.C.I. solid sustainer motor, presumably employing a cast charge of the type previously exhibited. This change, particularly beneficial to ship-board weapons, does not seem to have resulted in appreciable shortening of the rear body, so the motor tube must be fairly long. Another major change is a switch to the employment of boost units each consisting of a single motor of very high thrust. The four barrels appear to be connected by forgings, and their blunt noses are approximately in line with the tip of the nose of the missile body.

Full details may not be published concerning the guidance of Seaslug, but it is known to be a beam-rider. Chief guidance and control sub-contractors are G.E.C. and Sperry, and both these companies have borne a considerable part of the overall effort. Other companies which have been named include John Thompson Conveyor Co.; Sir Geo. Godfrey and Partners; Vickers-Armstrongs, Ltd.; Metropolitan Vickers, Ltd.; McMichael Radio, Ltd.; E.M.I. Engineering Development, Ltd.; and Imperial Chemical Industries.

An official statement reads as follows: "Seaslug is the medium weapon which is designed to engage any enemy bomber which evades the fighter defences of the Fleet. It will do so at any height which modern aircraft are capable of flying. The weapon has been developed by the Ministry of Supply and has been tested at Aberporth in Wales and Woomera in Australia. At Aberporth trial firings were made for the Clausen Rolling Platform, which is a mock-up of part of a ship's structure and capable of simulating all the conditions of roll and pitch likely to be encountered at sea.

"Seaslugs are fired from a triple ramp launcher which is automatically fed from a magazine below decks. The vast majority of firings which have been carried out at sea from H.M.S. *Girdle Ness*, the Navy's guided weapons trials ship, have been successful. Targets are detected at long distances by radar and plotted accurately for range, height and bearing. This information enables any particular aircraft to be selected as the target for the missile. Using this information the missile guidance and control system positions the weapon launcher, and the operator determines when to fire the missile, without even seeing the target. The Admiralty directed the development of all seaborne equipment, apart from the missile itself. This includes the launcher, magazine handling gear, radar and associated weapon direction and control equipment."

During recent months firing trials have been very satisfactory, and live targets have been successfully engaged. Quantity procurement is to be made and the first operational installations will be on the four guided weapon destroyers which are now under construction. These ships will be essentially enlarged developments of the *Daring* class. Meanwhile, the A.W.A. factory at Whitley has been completely reconstructed, and is now one of the finest guided-weapon facilities in the country.

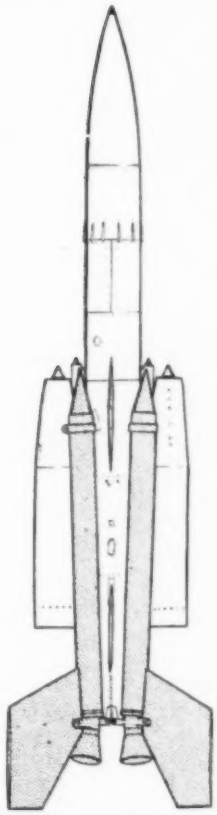
**AVRO** This company, like Armstrong Whitworth a member of the Hawker Siddeley Group, is the prime contractor for the stand-off bomb which will become operational with R.A.F. Bomber Command as a major part of the V-bomber weapon systems (certainly for the Vulcan and Victor). The task of developing such a weapon is very great, but at present no details of the chosen configuration may be revealed nor of the present status of development. It is pertinent in this context to refer readers to the article beginning on page 891. The company's Weapon Research Division were permitted to exhibit several items of "hardware" at the recent S.B.A.C. Show, and these give an indication of the breadth of the company's programmes in basic research.

**BRISTOL** Shortly after World War 2, the Bristol Aeroplane Company started investigations into the guided-weapon field, and this private work soon changed to officially sponsored development for the Ministry of Supply. The M.o.S. suggested an alliance with Ferranti, Ltd., and for many years the two companies have been equal partners in the development of the Red Duster* (Bloodhound) weapon system.

This exceedingly advanced ground-to-air system is very highly developed, and to it are committed four Bristol and two Ferranti factories which together employ "the largest workforce in Europe devoted to such a purpose." As we described in detail in our August 30 issue, the Bloodhound weapon itself is really a small aeroplane of extremely high performance, fired from a zero-length launcher by four solid boost motors, cruise propulsion being provided by a pair of 16in Thor ramjets by Bristol Aero-Engines, Ltd. The airframe, which is manufactured by Bristol Aircraft in Cardiff, is of very advanced form and has an outstanding two-axis control system effected by a pair of pivoting wings which can move either together or in opposition. The only other aerodynamic surface is a horizontal tailplane, the incidence of which is fixed. As the drawing shows, the cruise motors are mounted above and below the body, and each is fed with kerosine supplied by turbopumps fed with ram-air from an intake adjacent to that of each main engine.

Ferranti have handled the major part of the electronic and guidance effort. The Bloodhound has semi-active homing with a receiver dish in the nose of the missile picking up reflected radiation from the target while the latter is illuminated by a powerful ground radar. Irrespective of target evasion, the Bloodhound computer automatically follows the optimum trajectory for a collision course. The entire weapon system has been fully developed for operational service and should prove most reliable and trouble-free. Several hundred

* *Aviation Week*, September 30.



**Bristol Bloodhound (Red Duster)** Surface-to-air. Four wrap-round solid boost motors, two Bristol Thor ramjet sustainers. Overall length, 25ft 3in; body length, 22ft 2in; wing span, 9ft 3in; body diameter, 21in. Weights and performance data restricted.

development rounds have been fired in the development of the propulsion, guidance and other components, and the complete Bloodhound is now in production as the standard home-defence missile operated by the Royal Air Force. The launcher is made by M.L. Aviation.

No information may be published concerning possible developments of Bloodhound. It is, however, pertinent to record that Bristol Aero-Engines have exhibited the BRJ-801 ramjet, which is very much more powerful than Thor and has a diameter of 18in. More than 200 Bobbin twin-engined test vehicles were fired in the development of the earlier powerplant, backed up by extensive testing in the company's high-altitude test plant which can simulate altitudes up to 90,000ft.

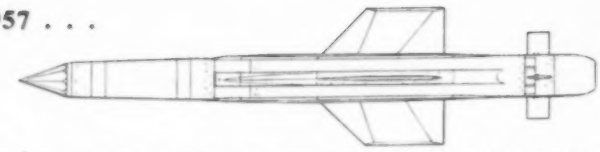
**DE HAVILLAND PROPELLERS** One of the three associated companies of the de Havilland Enterprise in the United Kingdom, de Havilland Propellers, Ltd., became involved in guided-weapon work in 1951. In that year the company received a contract from the Ministry of Supply for the development of a compact turbo-alternator to meet electrical power requirements of missiles developed by other companies. In the same year a second contract was received for the development of an infra-red homing head (on which early work had already been carried out at the R.R.E., Malvern). When these contracts had been successfully completed the M.o.S. awarded the company a development contract for a complete weapon system for an air-to-air missile with infra-red homing guidance. Originally scheduled under the project designation Blue Jay,* this weapon is now popularly named Firestreak.

Firestreak is of the usual "British" configuration, with cruciform wings and rear-mounted control surfaces indexed in line with

* *Aviation Week*, September 30.

***On the right is illustrated a complete Bristol/ Ferranti Bloodhound surface-to-air weapon, standing on its zero-length launcher. The shape of the pivoting wings is noteworthy.***

## Missiles 1957 . . .



**de Havilland Propellers Firestreak (Blue Jay)** Air-to-air. Solid sustainer motor. Length, 10ft 5.28in; body diameter, 8.67in; span of wings, 29.4in; span of controls, 19.1in. Weights and performance data restricted.

each other on a cylindrical body. The sharply pointed nose is built up from eight optically flat segments of material very transparent to infra-red radiation—probably some form of glass resistant to high temperature and abrasion. Inside is the homing head, in the development of which Mullard (one of whose directors, Dr. F. E. Jones, read a paper on infra-red, summarized in our issue of November 23, 1956) were brought in as sub-contractors, although de Havilland Propellers handled a very high proportion of the overall work themselves. In fact, virtually the only parts of Firestreak not designed and engineered by de Havilland Propellers are the warhead and the rocket motor.

The guidance and control system operates precision actuators which are apparently mounted ahead of the wings and move the control surfaces through rods carried outside the main body in four fairings. Each of the four wings is machined from a solid piece of light alloy and has a strong root flange through which axial rows of bolts attach the surface through the control fairings to the main body. The control surfaces are relatively small and are pivoted near mid-chord to a strong ring surrounding the propelling nozzle. The solid-propellant charge must be disposed close to the centre of gravity (just aft of the leading edge of the wings) and connected to the propelling nozzle through a motor tube. Around the latter is arranged a large toroidal air bottle which supplies all control and accessory energization. It seems fairly clear that Firestreak is an all-pneumatic weapon. Numerous D.H. Propellers missile accessories have recently been revealed; these were described in our issue of September 13 (page 445) and a further article on turbo-alternators appeared in last week's issue.

An account of the early development trials of Firestreak was published in our issue of May 3 last. So far as one can gather, the overall trials-programme has been satisfactory, and the missile has certainly been fired from a variety of aircraft at Aberporth and Woomera. Many of the trials at the latter range have employed the Avon-Sabre as the carrier, and —this aircraft not being designed to carry guided weapons—D.H. Propellers have evolved a neat package for the "aircraft" part of the Firestreak weapon system which fits a streamlined container under the Sabre fuselage. It is thus possible to convert any modern fighter to carry Firestreak in a matter of hours. In R.A.F. and R.N. service the weapon is carried on a standard pylon fitted with a non-expendable shoe through which pass the leads for hot and cold air and electric current.

Overall effort on the Firestreak is shared between all the U.K. plants of de Havilland Propellers. Hatfield is responsible for design, research and development; Lostock manufactures a proportion of the weapon (the remainder being sub-contracted) and is also responsible for assembly and testing; Farnworth carries out manufacture and assembly of development rounds; and a large new factory at Walkden is nearing completion and will handle all production assembly. The three last-named facilities are all in the neighbourhood of Bolton, Lancs.

Although no official announcement has yet been made to this effect, it seems fairly obvious that de Havilland Propellers is one of the prime contractors for the intermediate-range ballistic missile which is being developed in this country against M.o.S. contracts. Late last year a large steel structure was erected at Hatfield, and it is clearly employed in the cold-flow testing of an IRBM fuel system. No details of the weapon itself have yet been made public, but according to *Aviation Week* its development has been entrusted to three prime contractors; our American contemporary announces that "de Havilland Propellers apparently is the prime contractor on the IRBM programme and is building the airframe, with Rolls-Royce doing the rocket-engine work under a technical assistance agreement with North American Aviation, Inc., and Sperry developing the guidance system. Only static testing of the missile will be done at Hatfield."

**ENGLISH ELECTRIC** For more than eight years the English Electric Company has been one of the principal British guided-weapon contractors. The Company's guided-weapon division was formed in March 1949 for general research on behalf of the Ministry of Supply, with broad terms of reference. In the following year a development contract was placed for a complete weapon system for a land-based anti-aircraft weapon. Initially operations were conducted at Luton Airport in small premises formerly occupied by the Napier Flight Development Establishment, but English Electric now have a large establishment of their own at Luton, and since 1952 have operated an additional guided-weapon factory at Stevenage, Herts. Stevenage is now handling the bulk of the G.W. division's development and engineering effort.

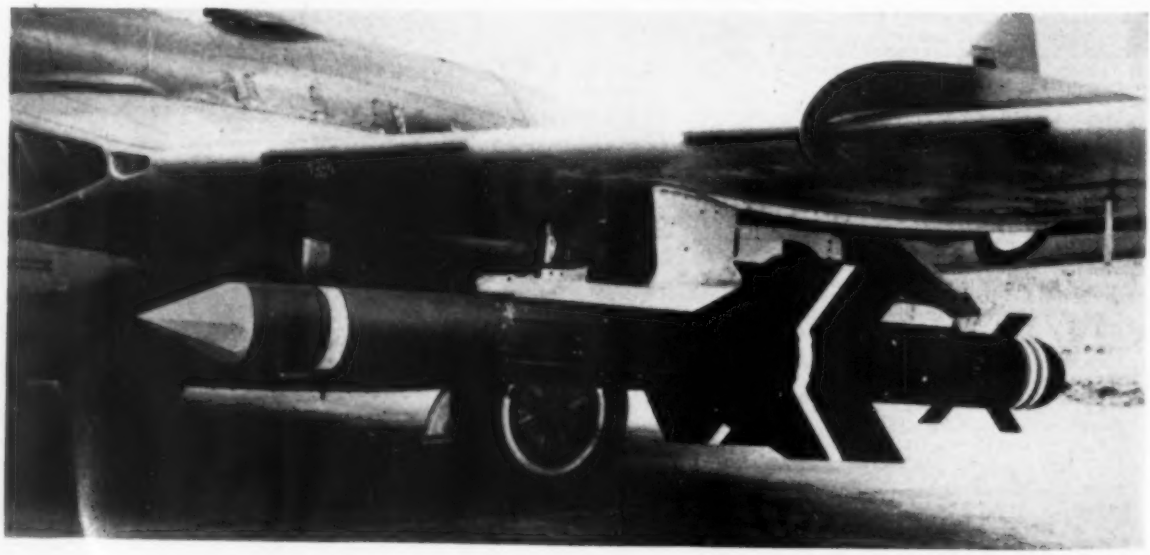
By far the most important project yet undertaken is the surface-to-air weapon system originally known as Red Shoes* and now named Thunderbird. It is the first of its kind in Britain to be ordered by both the Army and the Royal Air Force.

The missile itself is of classical "British" configuration with cruciform wings and rear control surfaces and wrap-round boost motors. Initially the body was truly cylindrical, with a high fineness-ratio and a constant diameter. Early in the development it was decided to sweep back the leading edges of the wings by 45 deg to alleviate aeroelastic problems and acute taper was also incorporated in the control surfaces. All the early development rounds had liquid-propellant sustainer motors by D. Napier and Son, Ltd. (a member of the English Electric Group) and four pairs of solid-propellant boost motors. The liquid sustainer-motors have now been developed into the Napier Double Scorpion aeroplane boost engine which recently set the new world altitude record for aeroplanes of 70,310ft (and believed to be destined for use in English Electric's P.1 supersonic fighter).

It was early decided that a liquid sustainer was not suitable for service in the field; and, when major advances in the efficiency of solid fuels were made a few years ago, a solid sustainer was specified for Thunderbird. To obviate c.g. problems it is usual to place the propellant charge for a solid motor as close as possible to the c.g. of the missile. The hot gases are then taken to the propelling nozzle through a motor tube of relatively small diameter. In order to minimize the length of the motor tube, the solid sustainer in the Thunderbird has a relatively short after-body. This in turn has led to a substantial increase in the size of the four control surfaces, in order to preserve their effectiveness when operating on the reduced moment-arm. In addition, the body diameter is increased by almost 5in in line with the wings, thereafter returning to its original value at the trailing edge. Only four boost motors are now fitted. They occupy the peripheral spaces left between the adjacent

**Aviation Week*, September 30.

*A de Havilland Propellers Firestreak infra-red air-to-air weapon mounted beneath the port wing of a Venom night fighter during development trials.*



pairs of wings and control surfaces. When the boosts burn out, air drag causes the four interlocked motors to slide backwards in their locating sockets on the missile body. At the rearward limit of their travel the front anchorages are released and the aerodynamic load on each boost nose-cone causes all four motors to pivot about the rear socket until that also releases, each motor being kept steady by its large fixed fin. When the boosts have gone the front sockets are sealed by small doors approximately 2in square.

Thunderbird is a semi-active radar-homing missile, obviously with a receiver aerial located at the front of a guidance package mounted within the large dielectric nose-cone. Large fairings presumably carry control-system equipment down each side of the body around the rocket motor and also provide anchorages for the four wings. These fairings suggest that the Thunderbird missiles seen so far are late-type test vehicles and not the final weapon which has presumably been re-engineered. Light alloy is widely used throughout the structure, the various body sections being centrifugal castings joined together by screws and bolts. The wings and control surfaces are all of trapezoidal section and are machined from the solid.

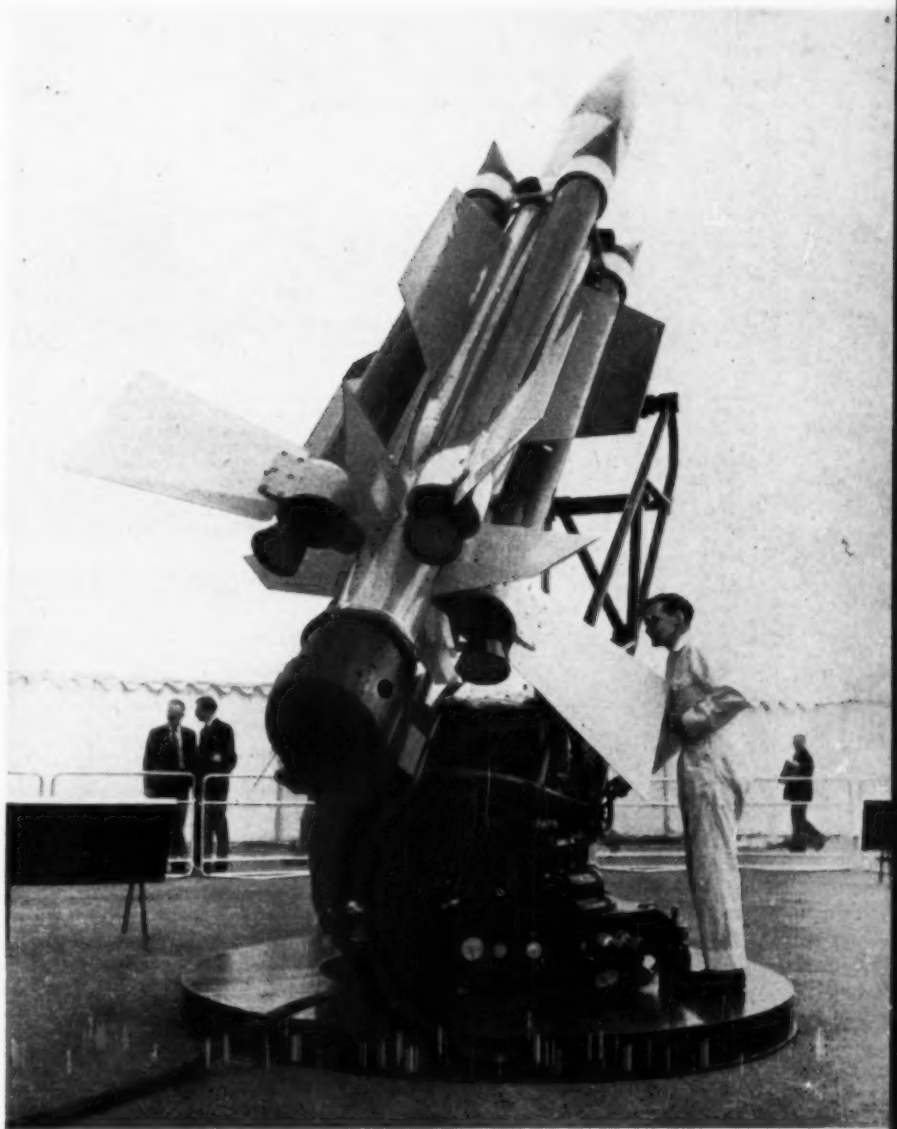
Some hundreds of test vehicles have been fired at Aberporth and Woomera since 1952, and a number of these have been recoverable rounds equipped with air brakes and a series of parachutes at the rear end of the body. Some of these rounds have been dropped from Lincoln aircraft to prove the recovery system, and others have been fired from the ground at Woomera with the four boost motors but without a sustainer. The company has the largest team of any of the U.K. contractors in Australia. English Electric has evolved a complete range of supporting devices, including ground check-out equipment, launchers and carrier vehicles. The launcher, shown in the photograph, is lifted by a single hydraulic ram to permit the missile to leave at any angle up to 90 deg. It is of the zero-length type, the missile standing on a rear base plate (through which all ground services are taken) and a pair of pivoting arms at the front which engage with lugs on the lower pair of boost motors.

The first production contract for Thunderbird was announced in the spring of this year on behalf of the British Army; a second production contract was placed at the beginning of September on behalf of the Royal Air Force. Personnel of both Services have for many months undergone training courses with English Electric and the complete weapon system is now in full production. The system has been planned to ensure reliability under arduous operational conditions and to minimize the problems of maintenance by replacement of packaged components. No details of the developments of Thunderbird may be published, but it is logical to deduce that such developments exist.

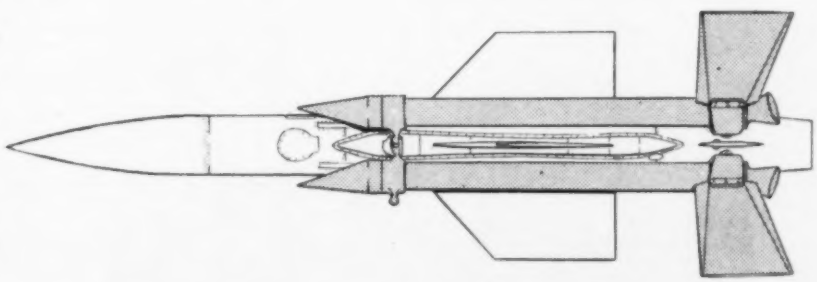
**FAIREY** This famous aviation company can probably claim to have been in the missile business longer than any other firm in the British industry, since a guided weapon for the destruction of Japanese *kamikaze* attackers was developed at the end of World War 2. The company's Research Division then undertook a varied range of rocket-propelled VTO and other projects before embarking in 1949 on studies in the field of air-to-air weapon systems.

From these early studies the company evolved the first British guided weapon to pass its acceptance trials; according to an American publication the weapon was originally known as Blue Sky, but to the world at large it has become famous as the Fireflash. The weapon system comprises a fighter aircraft fitted with a pencil-beam radar, a gun-sight, a simple "permission-to-fire" computer, a number of missiles and various aircraft-to-missile services.

As the drawing shows, the missile has an unusual configuration in that it comprises an unpowered dart which is accelerated to maximum speed by two solid-propellant boost motors, which are jettisoned immediately after burn-out leaving the round to coast for the remainder of its flight. During the boost phase the cruciform control fins are locked, and the unguided missile is spun about its longitudinal axis by the offset nozzles of the boost motors to minimize dispersion due to asymmetric thrust. At boost-separation the control surfaces are unlocked and the weapon is roll-stabilized to a

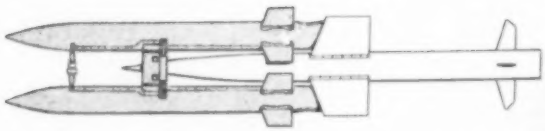


*English Electric Thunderbird semi-active homing surface-to-air weapon mounted on its zero-length launcher. This photograph clarifies the position and shape of the control surfaces, which in the drawing below are masked by the large stabilizing fins on the four boost motors.*

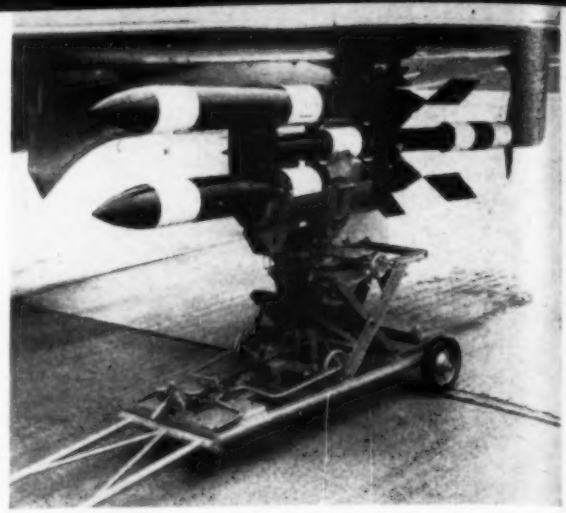


**English Electric Thunderbird (Red Shoes)** Surface-to-air. Four wrap-round boost motors, solid sustainer motor. Length (with or without boosts), 18ft 10.5in; body diameter, 20.75in over centre section (25.5in with wing fairing); span of wings, 66.75in; span of control fins, 63in. Weights and performance data restricted.

## Missiles 1957 . . .



**Fairey Fireflash (Blue Sky)** Air-to-air. Twin solid boost motors, jettisoned after burn-out (no sustainer). Overall length, 9ft 3.75in; body length, 89.05in; span across wing cruciform, 28.11in; control-surface span, 17.97in; overall height across cruciform of boost fins, 23.63in. Weights and performance data restricted.



*A Fairey Fireflash beam-riding air-to-air weapon being loaded on to a Hawker Hunter fighter by its ground-handling and lifting trolley.*

datum established at the launching. As soon as the roll error comes within specified limits the missile centres itself in the coded radar beam from the launching aircraft, and thereafter remains within the beam while the latter is held on the target by the pilot of the fighter.

As the radar beam is accurately harmonized with the axis of the pilot's gun-sight it follows that the only significant guidance error is that due to the aim-wander of the pilot/aircraft combination in tracking the target. Experience has shown that this factor is well within acceptable limits and the mean of many hundreds of firings has been less than the lethal distance of the proximity-fuzed warhead. Development trials were carried out on two-seat Meteors with the missiles carried at the tips of the wings. An underwing pylon has been successfully employed on the Hunter, and Fireflash is at present in full R.A.F. service with a squadron of Swift 7 fighters based at Valley.

An unusually full description of the missile itself was published in our issue of August 16. The rear body consists of an extruded and forged tube in a magnesium-ziconium alloy, into which is slid a two-rail chassis carrying the internal equipment. The motors are separated by a twin-piston unit containing 0.6 lb of cordite which is ignited when both charges are all-burnt. Control and guidance equipment includes a 3,000 lb/sq in air bottle, lateral accelerometers, an air-blown gyro assembly (a roll-displacement gyro and two rate gyros), the electronic receiver and power supply, the aerial assembly and the servo motor which positions the control fins. Design and development of all this equipment was handled by Fairey's Weapon Division, manufacture of certain items being sub-contracted; two companies which should be named are Plessey (receivers) and Ekco (fighter radar).

Fairey have over the years built up a most experienced team and a comprehensive range of environmental testing facilities with which a complete weapon system can be developed. It is not yet possible, however, to describe the project upon which their efforts are at present employed.

### SHORT BROTHERS AND HARLAND

For nearly six years this company's Precision Engineering Division has maintained a Guided Weapon Department at Castlereagh, near Belfast. Their first assignment was the responsibility of developing and manufacturing the valuable GPV (general-purpose vehicle) which, although superficially somewhat similar to the Folland RTV-2, is of later conception and has performed sterling service in the development of all aspects of guided-weapon systems (particularly those of the surface-to-air variety) and large numbers of rounds have been delivered. At the recent S.B.A.C. Show a sectioned GPV was displayed, incorporating a radar homing system designed and built by the Guilded Weapons Division of Elliott Brothers (London), Ltd. An accompanying picture shows a GPV actually striking a spherical target suspended from a balloon.

Very few details have been revealed concerning the SXA.5, but a specially prepared exhibition round has been publicly shown. In configuration the device comprises a cylindrical body with a fattened, square-section mid-portion carrying a cruciform of moving wings to provide control in pitch and yaw. At the rear is what seems to be a solid-propellant motor and a cruciform of fixed fins, of the same span as the wing cruciform and indexed at 45 deg. In construction the wings follow aircraft practice, there being a single wrapped-sheet aerofoil riveted to tip and root ribs and along the trailing edge. The fins were each riveted to a cylindrical casting provided with holes to admit air to cool the motor nozzle. Each fin had a mounting for a flare.

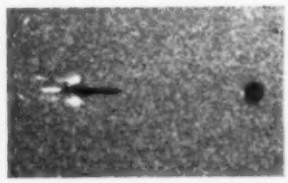
As exhibited, the device was labelled "round number 225" and it was carried on a pivoted base, locating with the motor outlet and four fins and leaving the weapon cantilevered at about 45 deg to the horizontal. The official description of the SXA.5 is "a multi-purpose surface-to-air test vehicle." Its configuration is such that the performance must be lower than that of other surface-to-air weapons and it very likely has radio command guidance. It would, therefore, seem to be intended for operations at relatively short range, possibly including surface-to-surface rôles.

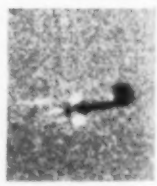
### VICKERS-ARMSTRONGS (AIRCRAFT)

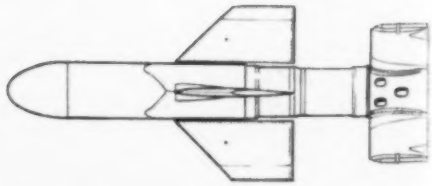
This famous aircraft company entered the guided-weapons field seven years ago and they have been working on operational weapon systems ever since. During this time they have tackled some challenging problems, and it is most unfortunate that, through no fault of their own, none of their products has yet been permitted to reach the production stage.

Their first major assignment from the Ministry of Supply was a 1950 development contract for a guided bomb, or air-to-surface weapon, intended to be matched to the Valiant and possibly other aircraft. The initial work

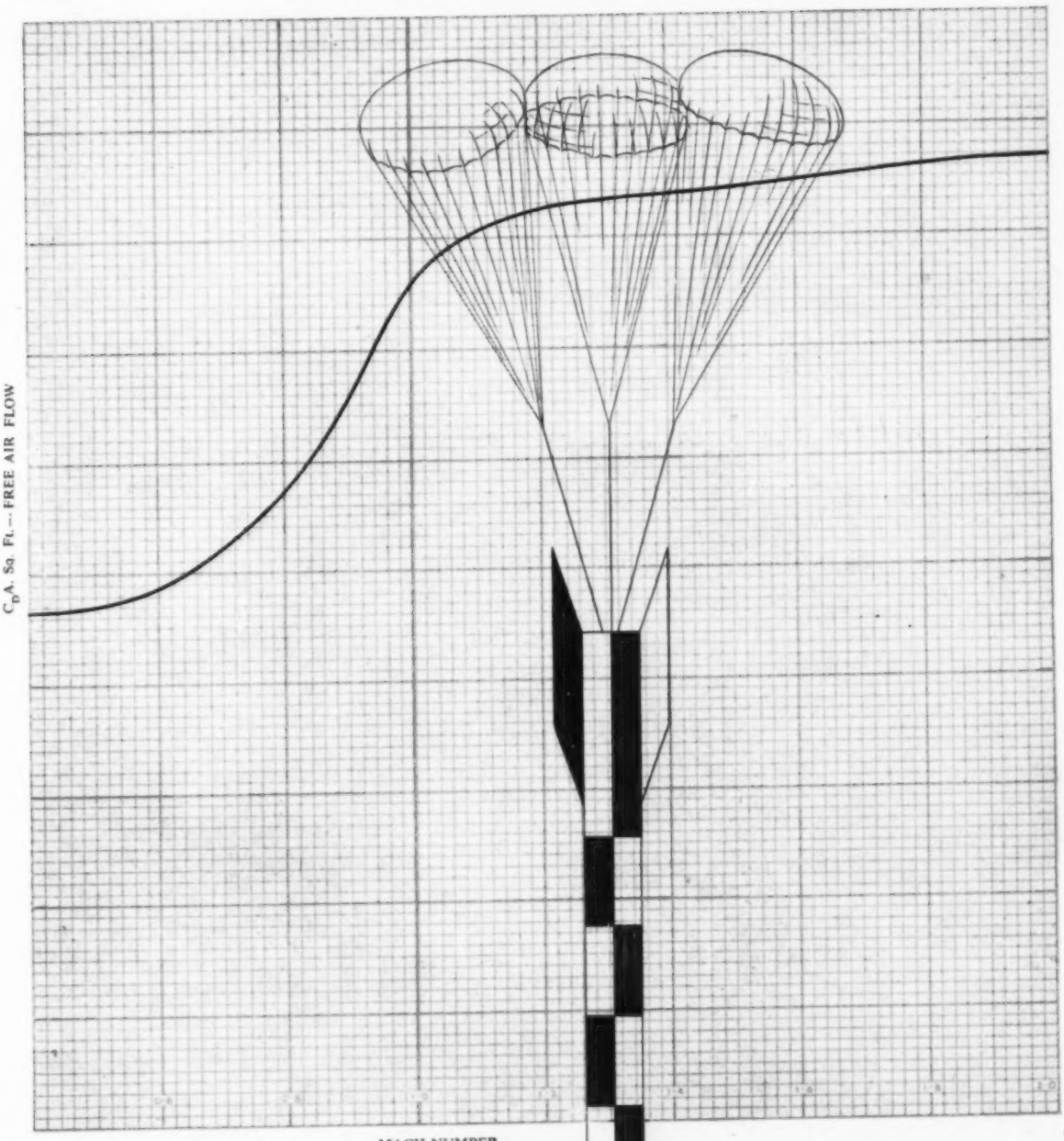
*Below, left, is the only photograph yet cleared for publication of the firing of a Short SXA.5 "multi-purpose surface-to-air test vehicle." The flame from the internal motor can be seen, together with small tracking flares. The two small pictures below depict the impact of a Short-built GPV (with homing radar) upon a small metal sphere suspended from a balloon.*







**Short and Harland SXA.5** Surface-to-air. Unstated means of propulsion. Overall length, as depicted, 77.2in; body diameter, 9.5in; span of wings, 31in; span of fins, 31in. Weights and performance data restricted.




Variation of Drag Area with Mach No.
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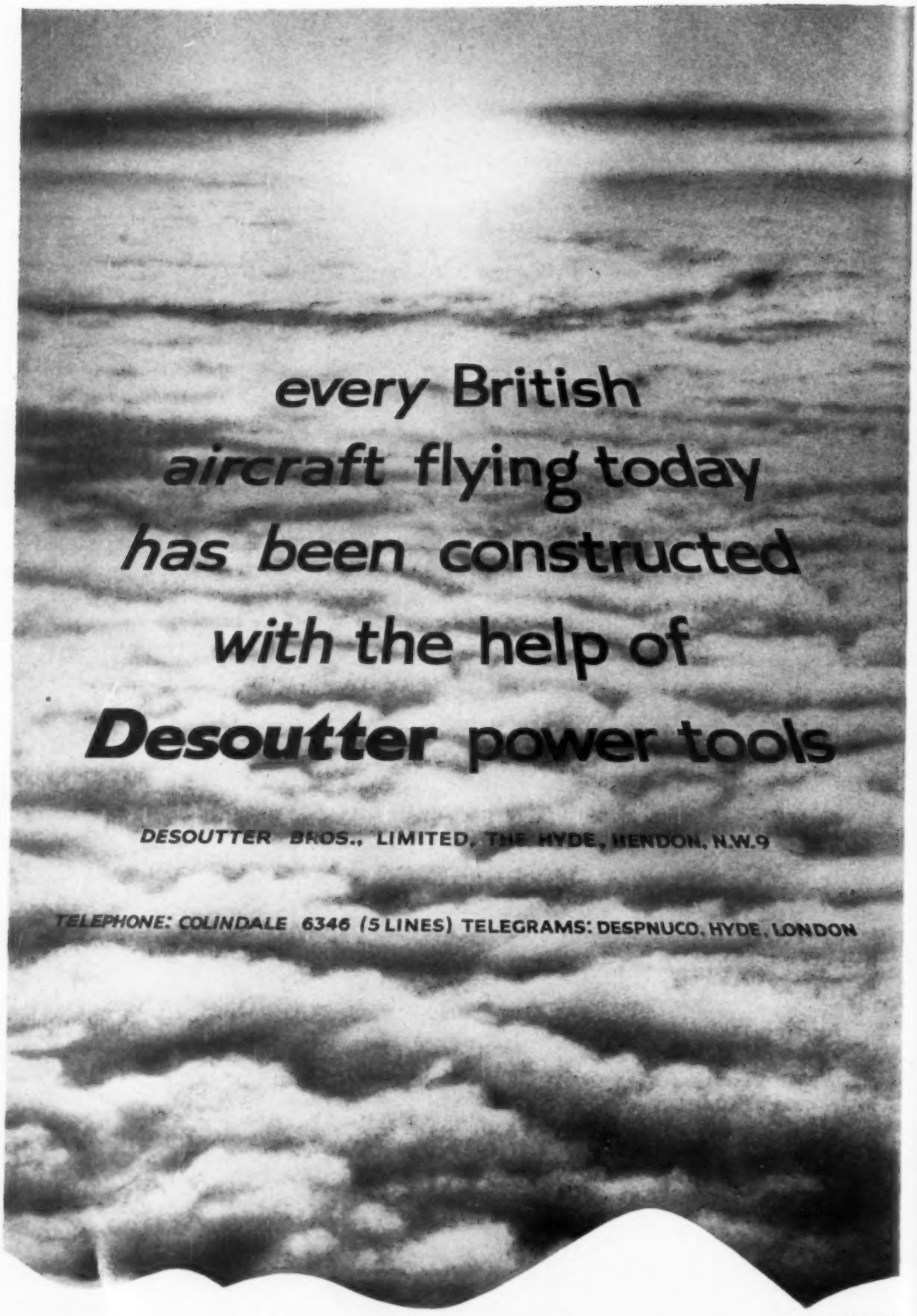
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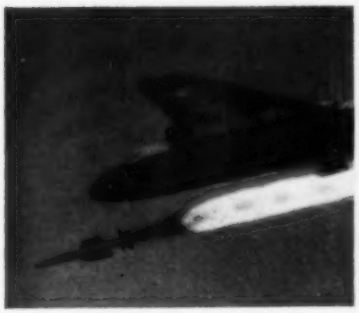
## Missiles 1957 . . .



*Left, Vickers-Armstrongs 888 (Red Dean) launched by a Canberra; right, developing firing of the Vickers-Armstrongs Type 891 from an experimental launcher. In operational service the 891 will be fired from its carrying case ("Flight," September 13, p. 449).*

on this much-needed device had already been done at the R.A.E., and Vickers were brought in to manage the programme with specific responsibility for airframe design and evolution of certain systems. Principal sub-contractors for guidance and control were E.M.I. and Smiths. In the following year work began on a second major project, a pilotless bomber powered by a Rolls-Royce turbojet and with guidance by Ferranti.

By 1952 the work had grown to such an extent that a Guided Weapons Department was formed at Weybridge. For five years this department has maintained a large and balanced team for the design, research and development of a complete weapon system, including environmental testing and flight trials. Attached to the G.W. Department is a facility for the manufacture and development of pre-production rounds. It is worth commenting that the company's engineers have, largely through force of circumstances, conducted a very great deal of research into such fields as reinforced-plastic construction and printed circuitry, and they have also designed and built an analogue flutter simulator.

Late in 1952, the Ministry of Supply requested Vickers to undertake the complete responsibility for a very advanced air-to-air weapon known as Red Dean. This missile was intended to be matched with advanced all-weather intercepter aircraft such as the "thin-wing Javelin development," and it accordingly carried a high development priority and absorbed a major part of the available Vickers design effort. The Vickers project number was 888.

As the drawing shows, the weapon has a classical British configuration with a long circular-section body carrying cruciform sets of wings and controls indexed in line with each other. Compared with Firestreak the weapon has control surfaces of higher aspect ratio and greater area, and they are clearly mounted on an actuating ring passing around the rocket motor tube joining a solid sustainer charge to a propelling nozzle. Control fairings can be seen extending down the sides of the body in line with the wings and control surfaces.

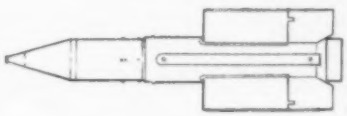
As far as one can gather, Red Dean is the largest air-to-air missile to have reached an advanced stage of development. Its size indicates either that it has a relatively short range, poor guidance and an exceedingly large warhead or, alternatively, a long range and very sophisticated guidance. Of these two alternatives the latter seems much more likely, in view of the fact that the missile was intended to accomplish difficult all-weather interceptions. Vickers had reached an advanced state of development in the summer of last year and had prepared all the ground gear, loading trolleys and checking systems. The weapon itself had completed an appreciable part of its initial air-firing trials, and was frequently seen under the wings of Canberras operating from Wisley. Nevertheless, it was decided to discontinue development for several reasons, chief of which was the cancellation of the development contract for its carrying aircraft. Cancellation of Red Dean finally took effect in June of this year.

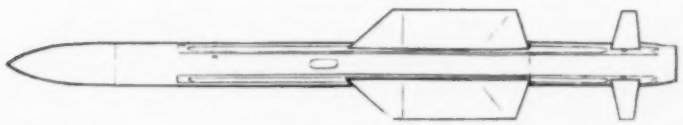
About eighteen months ago the Guided Weapons Department were in the unhappy position of watching all their officially sponsored projects collapsing like a house of cards, and it was decided that the logical thing to do would be to find a good project which could be embarked upon as a private venture. Anti-tank problems had already been examined at Weybridge, and the company decided to develop a multi-purpose weapon capable of being carried by a foot soldier and used against armoured vehicles and possibly other "hard-skinned" targets. The philosophy governing the development of this weapon was determined by what a man on a battlefield can carry in one hand. It has clearly enforced upon the Vickers designers extremely simple guidance and control, and the minimum warhead capable of destroying the heaviest armoured vehicles.

The Vickers infantry anti-tank weapon is known as Type 891 and its existence was revealed three months ago. The basic round consists of a conical nose housing various alternative types of warhead (some of which are highly likely to have a hollow charge) detonated by a contact fuse. The rest of the body is a cylinder formed from wrapped metal sheet, and the rear part houses a rocket motor charged with a smokeless solid propellant supplied by I.C.I. Lift and control is provided by a cruciform of wings, each of very low aspect ratio and apparently fabricated from solid reinforced plastic material. The rear part of each wing is hinged to control the flight of the weapon. The complete round is carried in a box, which in production will probably be manufactured from glass fibre and will provide full protection against rough usage. When the infantryman has found a target he opens the box, points it in the direction of firing and sights on the target through an optical viewer resembling a pair of binoculars with a pistol grip. The viewer is attached to the weapon-box through a short cable, and the round is fired by a trigger in the pistol grip. During the launching the missile is initially restrained by a lug engaged with a rail along the top of the inside of the box, and thereafter is controlled by command guidance transmitted through a thin wire unwound from a coil inside the box. The very small span facilitates steering the weapon down roadways, under telephone cables and through thinly wooded areas without hitting obstructions, and the optical command guidance should be extremely accurate once the operator has gained some experience.

Development of the 891 is approximately 50 per cent completed. The overall programme has moved exceptionally rapidly, partly owing to the experience of its designers and partly owing to the simplicity of the weapon system. Most of all, however, the rapidity of development has been due to the fact that the company have had freedom of decision without disruption through incessant change of specification. The weapon has not yet been adopted by the British Army, but is obviously being planned to meet all requirements for such weapons, and it should find a ready market throughout the world.

**Vickers-Armstrongs Type 891** Surface-to-surface. Solid sustainer motor. Length, 32.25in; body diameter, 4.5in; wing span, 11in; weight of weapon in carrying case, with optical tracking sight and cable, 35 to 40 lb.





**Vickers-Armstrongs Type 888 (Red Dean)** Air-to-air. Internal sustainer motor. Length, 16ft 1in; body diameter, 12.5in; wing span, 45in; span of control surfaces, 45 in. Weights and performance data restricted.

## Australia

SINCE the vast Commonwealth of Australia accommodates the principal centre for guided-weapon testing outside the U.S.A. and U.S.S.R., it is logical that that continent should undertake the development of a complete weapon system. The first such system which can be publicly referred to is an anti-tank weapon with the aboriginal name Malkara. Designed to a British Army requirement, the Malkara is being developed at the Government Aircraft Factories in Melbourne (by essentially the same team as that which produced the Jindivik) in association with other organizations and the Weapons

## Missiles 1957 . . .

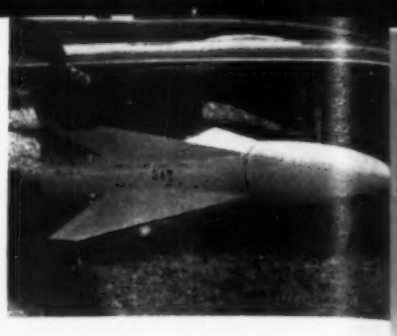
Research Establishment. One can probably assume that Malkara will be a larger weapon than the Vickers 891, since the latter was planned to fill a gap in existing systems.

# Canada

**Sparrow II** This air-to-air weapon was developed from the original Sparrow I family by Douglas Aircraft, who matched it particularly to the F5D Skylancer naval intercepter. When the latter was terminated the weapon also was cancelled.

In 1956 the Canadian government selected Sparrow II as the future air-to-air weapon of the R.C.A.F., replacing the defunct Velvet Glove (see our 1956 review). Avro Aircraft were appointed system manager, with Canadair building the airframe, and Canadian Westinghouse, at Hamilton, given the responsibility for guidance. It was unofficially reported in the U.S.A. nine weeks ago that the programme was held up pending a decision on the type of guidance to be used; the American weapon had active-homing radar, with Bendix-Pacific prime contractor for this portion.

**New A.S. Weapon** It was unofficially reported in April that the Canadian Armament Research and Development Establishment have designed and developed a new homing torpedo intended for air launching against submarines. It is stated to be scheduled to be issued to the R.C.A.F. and R.C.N. very shortly.



**Nord 5.103** Air-to-air. Solid sustainer motor, the first portion having greater thrust and providing boost propulsion. Length, 98.45in; span, approximately 36in; firing weight, 280 lb; burn-out speed, quoted as Mach 1 in an official table, but actually Mach 1.7; maximum range, 4,375 yd.

*Left, above: Maruca; upper right: Nord 5.103 under the wing of an Aquilon (Sea Venom) naval fighter. The latter weapon is unusual in being devoid of aerodynamic controls.*

# France

## AIR-TO-AIR

**Matra R.510** In several ways this weapon is most unusual, yet it has successfully passed its final acceptance trials and is in the pre-production stage. Guidance is based upon signals from an auto-director photocell, mounted behind a window in the extreme nose with a field of view within a 20-deg cone, which senses luminous contrast and fixes the angular co-ordinates of the target. The subsequent system, energized by a 27-V battery, incorporates an autopilot in which are sensing units for speed and angular acceleration, an electronic group finally combining the signals from the auto-director photocell with the accelerometer readings and amplifying the resulting guidance in several stages. The final stages feed the servos which actuate the canard foreplane and the rudder beneath the rear body.

Propulsion is provided by a two-stage solid-propellant motor, the first stage being a high-thrust boost charge. Lift is obtained from a rear-mounted wing with dihedral, and certain types of 510—there are numerous superficially different versions—have twin rear stabilizing fins. The warhead, which is detonated by a proximity fuze, has an explosive charge of no less than 66 lb; it operates by the projection of fragments in a plane normal to the major axis of the missile. The R.510 has been exhaustively tested from Meteors, Canberras and other aircraft, and two or four can be carried by the Mystère, Trident and Vautour on underwing pylons. Production rounds are delivered in two portions (one containing the motor and warhead), packed in environment-proof containers.

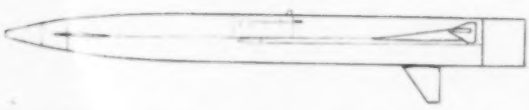
**Nord 5.103** With the Matra R.510 this weapon is the most highly developed air-to-air system in France; and it is similarly of a relatively early conception. Guidance is effected by radio command, the launching aircraft having a transmitter for pulses which are coded to permit several aircraft to control their own missiles without confusion and without great risk of enemy jamming. The controller actually has a small control column, like a drone "beep box," with which he keeps the 5.103 aligned on its target. Control is effected solely by deflecting, or masking, the jets from the twin motor nozzles.

During its flight the missile is slowly turned about its longitudinal axis by the alignment of the cruciform of very swept wings. The whole configuration is very reminiscent of that of the 5.210 (S.S.11) by the same firm. Propulsion is by a two-stage solid motor, the first-stage charge giving quick acceleration up to the steady cruising speed. The 5.103 can have either a training head or, by a simple change-over operation, a warhead with a very heavy charge. Detonation is effected by a proximity fuze, and a self-destructor is fitted should the miss-distance be too great. The missile is in pre-production for intercepters of the French Air Force and Navy and could be readily produced in great numbers.

*A development Matra R.510 (M.510) air-to-air weapon carried by a Meteor N.F.11.*

## AIR-TO-SURFACE

**B.B.10** At present this is the only air-to-surface missile in the French armoury which may be publicly described. Developed chiefly by Sud-Aviation, to form part of the weapon system for the Vautour and Super Vautour attack aircraft, the B.B.10 is quite a large weapon with a warhead charge of some 400 lb. At the rear is a smokeless solid sustainer motor and a cruciform of fixed fins with an annular surrounding shroud. Guidance is effected by radio command from the launching aircraft, which can apparently "see" the target from the optical window in the nose of the weapon, possibly by a television link. The trajectory is controlled by a cruciform of fore-planes.



**Matra R.510** Air-to-air. Solid sustainer motor, the first portion having greater thrust and providing boost propulsion. Length, 10ft 5.9in; body diameter, 11in; wing span (10 deg dihedral), 39.4in; firing weight, 374.8 lb; burn-out speed, Mach 2; altitude limits, 9,800 to 49,200ft; maximum range, 8,750 yd.

**Sud Aviation B.B.10** Air-to-surface. Solid sustainer motor. Length, about 11ft; span of rear fins, about 32in; launching weight, probably more than 900 lb; performance data restricted.

## SURFACE-TO-AIR

**Malafac** Now under intensive development for the French Navy, Malafac is a high-performance ship-to-ship bombardment weapon launched from a ramp by an S.E.P.R. tandem boost with four large fixed fins. No details of the configuration of the weapon itself may be published.

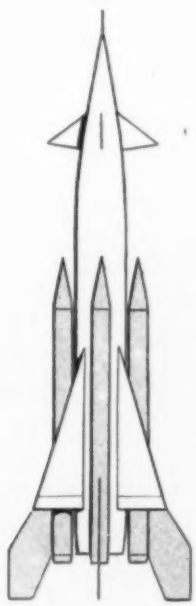
**Maruca** Shown in an accompanying photograph, this D.E.F.A. device is performing two important functions for the French Navy; it is serving as the test vehicle in the development of numerous airborne components destined for the Masurca, and it is acting as a training missile in such subjects as ground-handling, storage, firing and tracking. A photograph shows it in a configuration with four finned boost motors (which do not accelerate it beyond Mach 1). The configuration is that of a small aircraft, and tracking flares are carried on the wing tips.

**Masurca** Under this designation the French Navy are developing a ship-to-air weapon system "destined to be the chief defensive weapon of naval craft against aircraft of very high performance." No details are available.

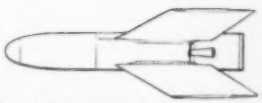
**PARCA** The name of this well-known anti-aircraft weapon is formed from the initial letters of its function: *projectile autopropulsé radioguidé contre avions*. The overall programme for this weapon began at least seven years ago, under the direction of the Army Chief of Staff (Etat-Major); development has been managed by the D.E.F.A. (Direction des Etudes et Fabrications d'Armément). Most of the work has been done at Verdon, Versailles, Puteaux and Bourges.

Superficially, PARCA could be called a cross between Nike Ajax and Thunderbird. It has the delta wings and canard foreplanes of the American missile, matched with the four wrap-round boosts of the British system. Construction is quite conventional, the body being assembled from light-alloy cylindrical sections and the wings being machined from solid. The boost motors are S.E.P.R. solid charges, each case having a swept stabilizing fin and falling clear individually. Sustainer propulsion is effected by a liquid-propellant motor, almost certainly an S.E.P.R. acid/kerosine unit.

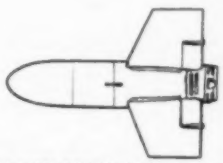
A French report describes the guidance in the following terms: "A tracking radar follows the target aircraft and continuously directs the elevation and azimuth of a remote-control firing ramp ahead of the target. This reduces the amount of manoeuvring which the missile has to perform, and so gains precious seconds. Upon firing . . . the four boosts accelerate the weapon . . . and are jettisoned. The PARCA is tracked from its launching point and aligned with its target by radar command. Two direction-finders are employed to measure the angular co-ordinates of the target and missile, and keep these parameters in the proper relationship until the weapon is near enough to be detonated by its proximity fuze."



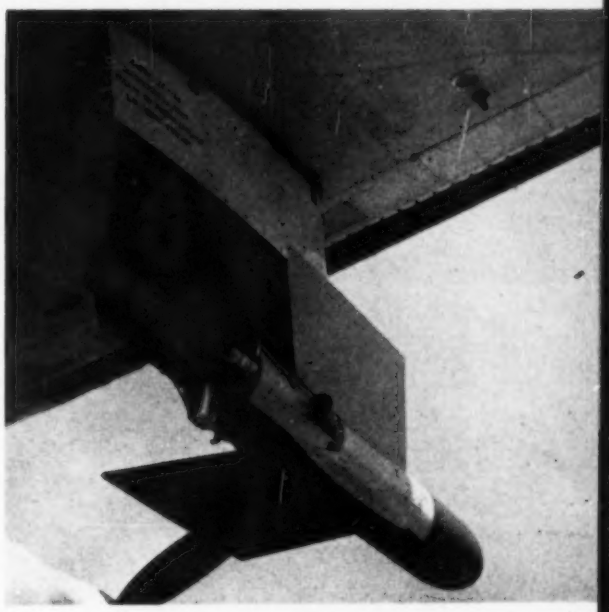
**PARCA** Surface-to-air. Four wrap-round solid boost motors, liquid-propellant sustainer. Length with boosts, about 18ft; body length, 16ft 8.5in; span, 63in; firing weight, about 2,200 lb; burn-out speed, Mach 1.7; maximum altitude, 82,000ft.



**Nord 5.210 (S.S.11)** Surface-to-surface and air-to-surface. Length, about 48in; span, about 26in; firing weight, about 40 lb; cruising speed, 435 m.p.h.; range, up to 3,830 yd.



**Nord 5.203 (S.S.10)** Surface-to-surface and air-to-surface. Solid sustainer motor. Length, 33.86in; span, 29.53in; firing weight, 33 lb; cruising speed, 186 m.p.h.; maximum range, 1,750 yd.



*A Nord 5.210 (S.S.11) wire guided missile carried by a Dassault Flamant aircraft.*

PARCA's brochure performance is insufficient for it to be quite effective against modern aircraft, and Mr. James Hutchinson, M.P., claimed recently at Vernon: "It cost £10m to develop a weapon which seemed to me almost identical to a weapon produced by us two or three years before." This is perhaps slightly unjust, and PARCA is, in any case, only the first of a family of weapons. It is coming into French Army service.

**S.S.10** Developed from the earlier S.S.9 (S.S. = *Sol-à-Sol*, surface-to-surface), the S.S.10 (Nord 5.200 series) is one of the smallest and cheapest guided-weapon systems in the world, and it is the only system outside the U.S.A. and U.S.S.R. to be widely used by actual operational formations. It is virtually the pioneer wire-control system of the German X-4/7 matched to a very simple and well-engineered tactical weapon system for use by light aircraft, helicopters or foot soldiers against armoured vehicles or other hard-skinned targets.

Chief constituents of the S.S.10 are a cylindrical body, with an ogive nose and an untapered rear-portion containing a smokeless solid rocket sustainer. There is a cruciform of wings (which, owing to the low flight velocity, are relatively large), and the flight of the missile is controlled by twin wires unwound from bobbins within the weapon, through which pass electrical command signals from an observer, who keeps the clear rocket flame aligned with the target. The aerodynamic control is effected by small spoilers on the trailing edges of the wings. The weapon spins slowly about its longitudinal axis.

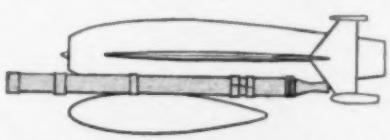
For training purposes, the Nord 5.202 has an inert warhead, and costs approximately $915. The operational 5.203, costing about $970, has a shaped charge capable of piercing up to 400 mm of armour, the complete warhead and all-ways impact fuze weighing about 11 lb. Warhead and missile-body are packed separately and are assembled in the field by pinning three simple latches. The carrying case provides protection against all climates, and serves as the launcher when the weapon is operated by infantrymen.

With a little experience an operator can expect to obtain about 80 per cent hits at ranges between 400 and 1,600m (984 to 5,248ft). During manoeuvres at Mailly last summer 61 S.S.10s were fired under representative operational conditions, scoring 86 per cent hits, and as high as 90 per cent has been recorded by the French Air Force. Both these services use the weapon in great numbers, the monthly production rate being about 400 to 500 rounds. Sweden and Western Germany also use the S.S.10, and during the Suez campaign it was successfully employed by Israel against Egyptian armour.

**ENTAC** In all essentials this weapon is similar to the Nord 5.200 series, and is similarly designated S.S.10. It is, however, manufactured by the D.E.F.A. and not by private industry. The name is formed from *Engin Tactique Anti-Chars*.

**S.S.11** A logical extension of the S.S.10 system has resulted in this much improved weapon. Preliminary studies stemmed from basic surface-to-surface evaluations of the earlier system, but the S.S.11 is now a highly flexible device capable of being fired from any ground position or any aircraft with a reasonably low speed.

The missile of the S.S.11 system is the Nord 5.210 (there is as yet no government-built D.E.F.A. counterpart). In detail this weapon is completely different from the more rudimentary 5.200, the motor having twin nozzles on either side of the body and control being effected by interference with the two jets to give asymmetric thrust. The rear body and control system are in many respects similar to those of the 5.100 series of air-to-air weapons by the same manufacturer. Training and opera-



**Sud Aviation S.E.4.200** Surface-to-surface. Two solid boost motors, integral ramjet for cruise propulsion. Wing span, 7ft 1in; approximate length (excluding boosts), 10ft; launching weight, 660 lb; cruising speed, about Mach 0.9; ultimate range, about 74 miles.

# Missiles 1957 . . .

**Contraves C.7** Air-to-air. Solid sustainer rocket motor. Approximate dimensions: length, 7ft 10½in; span, 18in; body diameter, 4½in. Estimated weight, 120 lb.

*Contraves Italiana MTG-CI-56 surface-to-air weapon.*

tional missiles of the S.S.11 series cost about $1,370 and $1,510, respectively. Final acceptance trials and general indoctrination is being conducted by a combat unit in North Africa. Already the 5.210 is in production for the French Navy and it is to be exported to several countries.

**S.S.22** This is the latest family of small tactical weapons to come from the S.N.C.A.N. and D.E.F.A. It is reported to be basically an improved S.S.11 equipped with radar guidance (i.e., no wires). The weapon system is considered potentially suitable for surface-to-surface and air-to-surface use (like its predecessors) and also for air-to-air operations.

**Sud-Aviation S.E. 4.200** Developed during the past seven years by the S.N.C.A. du Sud-Est (now Sud-Aviation), the 4.200 is a unique cruise-type, winged, air-breathing bombardment weapon, now coming into limited use with the French Army. Despite its moderate (subsonic) performance, it is powered by an integral ramjet, burning kerosine contained in internal tanks. A large, high-exposive warhead is suspended in a fairing beneath the body.

From a simple ramp, which can be on a vehicle, the missile is launched by two long-burning boost motors, each of which falls away at the burn-out point; early development rounds had the boosts above and below the weapon, on the vertical centre-line. Guidance is effected by radio-command, operating through an autopilot which controls the wing-tip rudders and trailing-edge elevons (there is no horizontal tail). A telemetering receiver plots the position of the missile and at the appropriate point the radio transmitter gives the order to dive on the target.

## Italy

TWO of Italy's first missiles were revealed at the Technical Salon in Turin in October. These weapons, which are described below, are not the only ones in Italy's armoury, but very few additional details are available.

During testing in Sardinia—the chief Italian surface base for guided weapons—a device designated MR.27 is stated to have performed well, following the correct trajectory under radio command. A surface-to-air weapon, capable of "operation" at 60,000ft, MR.27 is small, being 1.5 m (59in) in length and weighing 24 kg (52.9 lb). Burn-out speed is reported to be 1,500 km/hr (932 m.p.h.) and range 30 to 40 km (19 to 25 miles). Other systems include the AR.4, built in Turin, the CS.1 built in Rome by Contraves and the AR.15 built in Livorno. The AR.15 is an intermediate development stage intended to lead to a large surface-to-air weapon. Developed by Whitehead-Motofides at Leghorn, the AR.15 has a liquid-propellant sustainer and is being tested in Sardinia. Anti-aircraft missiles are to be fitted to the new cruiser *Garibaldi*.

Although purely experimental, the AR.14 is also worthy of brief note. This device is the latest in a series of small rocket vehicles, and is described as having a motor which "automatically feeds itself," together with beam-rider guidance. Length is given as 7 m (23ft), but the weight, quoted as 50 kg (110 lb), is probably actually 500 kg. Motor thrust is 2,205 lb for 29 sec, burning WFNA and kerosine, and the programme is stated to end at 10,000 m (32,000ft), with 20,000 m as an eventual target. Testing is going on at the Sardinian base at Salto di Quirra.

**MTG-CI-56** The Italian firm of Contraves Italiana, an associate of the Swiss Oerlikon company, hold licences to manufacture the Oerlikon 54 and 56 surface-to-air weapon systems. An accompanying picture shows a display Contraves missile of this family. Production is just beginning at Rome.

**C.7** This remarkably small and neat air-to-air missile has been developed by Contraves, in collaboration with the Centro Razzi (rocket centre), who for many years have investigated infra-red homing guidance. The C.7 is the first outcome of this work, which is reported to have been financially assisted by the Italian and Dutch ministries of defence. Propulsion is provided by a solid sustainer tube fitted with a cruciform of stabilizing fins. To this is attached a yellow-painted fore-body carrying the I.R. seeking head under a glass dome and a pair of horizontal rectangular wings machined from solid.

On the wings are electric terminal blocks and "intermediate partitions" or fences, of which there are two on each semi-span. Control is apparently effected by twist-and-steer, the wings moving together or in opposition. Drag is clearly quite low, and the C.7 should be able to retain control effectiveness for some miles after motor burn-out. The weapon has been fired a number of times from F-86s, but at the time of writing had yet to be launched against an aerial target.

*Sud-Aviation 4.200 ramjet bombardment missile, mounted upon its launcher.*

## Japan

SEVERAL somewhat timid steps are being taken to effect an entry into the guided-weapon field on a broad front. The only operational system likely to become effective in the near future is the Swiss Oerlikon 56 (*q.v.*), for which Mitsubishi Electric Machinery Co. hold provisional rights to the weapon and its manufacture. Under a 15-year contract Oerlikon will receive 8 per cent as patent rights on the missiles and 5 per cent of revenue from the launchers and fire-control system. A complete set of weapons and a launcher have just been imported at a cost of $1,080,000.

Mitsubishi Heavy Industries have spent 2.4m Yen on the TMB-0 research missile, with command guidance, and have a 10m Yen programme for the TMA-1 air-to-air research system. TMA-1 consists of a 1.6 m (63in) fore-body, weighing 40 kg (88.2 lb) and having a diameter of 5.9in; and a 1.3 m (51.2in) rear portion, weighing 70 kg (154.3 lb). Design speed is Mach 1.6. During three months of trials TMA-1 has not yet been successfully fired. Shin Mitsubishi have a smaller air-to-air device called MM-1. This weighs 45 lb, and has guidance by Mitsubishi Electric Machinery and a rocket motor by Fuji Precision Machinery. Finally, since the autumn of last year Kawasaki have been conducting basic research and development into an anti-tank weapon 1 m (39.37in) long; six other companies are assisting in turning it into a weapon system.

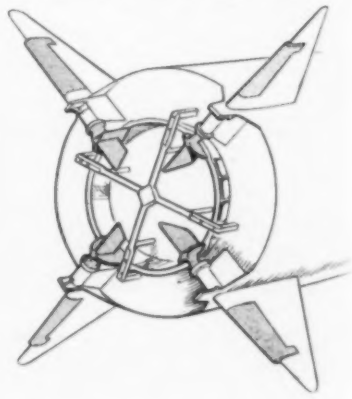
## Soviet Union

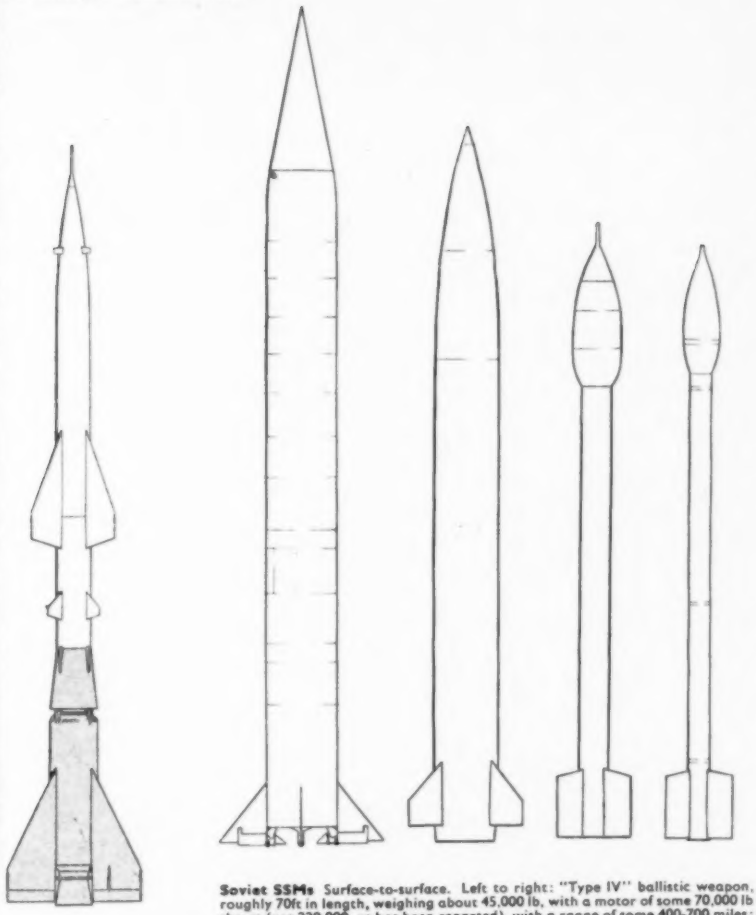
SO much pure invention has been published as representing a true picture of guided-weapon development in the Soviet Union that the following is based solely on the actual "hardware" which was publicly displayed in Moscow on the 40th anniversary of the October Revolution. In the writer's view everything then revealed was in all respects genuine, and in no way disguised to mislead an observer. The designations are so far not known in the West (publicly, that is), and the following are merely functional appellations, i.e., "SAM" indicates "surface-to-air missile."

**SAM** Leading all other guided-missile sections in the parade through Red Square was a unit, believed to be of the Red Air Force, armed with a surface-to-air guided weapon. First came four utility cars each accommodating six officers or technicians. Following these were standard (Ford-derived) 6×6 tractors and articulated trailers each carrying one round. As far as one can gather, there is no reason why the lengthy rail carrying the missile should not also serve as the launcher, thus effecting great economy in vehicles and making the whole system mobile.

The basic weapon is apparently guided by beam-riding and radar command (like Nike Ajax), there being a quartet of blade aerials around the pointed, probe-carrying nose. There are cruciforms of wings and rear con-

***The propelling nozzle of the largest of the Soviet ballistic weapons described on the opposite page (the nozzle has a sealing plug and control surfaces are shaded).***





**Soviet SSMs** Surface-to-surface. Left to right: "Type IV" ballistic weapon, roughly 70ft in length, weighing about 45,000 lb, with a motor of some 70,000 lb thrust (not 228,000, as has been reported), with a range of some 400-700 miles; "Type III", ballistic weapon, roughly 35ft long, weighing in the region of 10,000 lb, with a liquid-propellant motor and a range of the order of 50 miles; "Type II", unguided tactical weapon, weighing about 6,000 lb; and "Type I", unguided tactical weapon, weighing about 4,000 lb.

**Soviet SAM** Surface-to-air. Internal sustainer fired at same time as solid boost motor. Length with boost, about 30ft; basic missile length, about 21ft; firing weight, probably about 1,500 lb without boost; slant range, apparently of the order of 15 to 20 miles.

trols, all of low aspect ratio. At the rear is a tandem boost motor, which seems to give high thrust for a relatively brief period. It is attached via a hollow thrust-casting which clearly is designed to permit the missile's own sustainer to fire at the same time. Overall performance of the weapon should be good, particularly since it has all the hall-marks of being a genuine, fully cleared system already in operational use.

**SSM Type I** In the parade were eight tracked vehicles based on the JS.3 chassis, each carrying an elevatable launcher for an unguided, spin-stabilized ballistic rocket similar to the U.S. Army's Honest John. It is not known whether the launcher can be traversed, but it can certainly be elevated to a high angle.

**SSM Type II** Eight tracked vehicles, similar to those used for the "Type I" weapon, each carried an armoured superstructure on which was mounted a somewhat larger, spin-stabilized tactical-support missile. The weapon was carried concentrically within a cylindrical housing consisting of massive upper and lower halves clamped together and obviously intended to protect the weapon (and possibly warm the propellant charge) and provide a film mounting when traversing rough country.

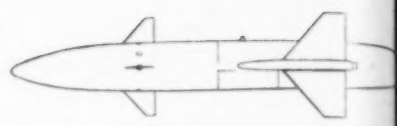
**SSM Type III** Two vehicles, identical with those used for "Type II" weapons, each carried an appreciably larger missile in an elevatable launcher. There are indications that this missile is placed upright on its tail before firing and is provided with guidance to strike a target deep in the rear of an enemy ground force. The fins appeared to be movable.

**SSM Type IV** Reminiscent of the German A.4 (V-2), these large ballistic missiles, of which there were two, were carried on articulated two-axle trailers towed by half-track vehicles accommodating a crew of sixteen (excluding those in the cab). The weapon itself could be seen to have aerodynamic rudders and refractory vanes in the jet of the large motor, the latter having all the indications of using liquid propellants.

It has been asserted that this weapon is, in fact, the Soviet ICBM. This is undoubtedly not so; the range is not even in the IRBM class of around 1,500 miles, and is in all probability much less than half the latter. Another report identifies the missile as the "T-2" (a whole family of "T" weapons has become known in the U.S.A., and their detailed specifications are frequently published), and claims that the thrust is 228,000 lb. The only fact which can be stated with assurance is that the weapon is not the latest in the Russian ballistic arsenal, and firings of devices with a range of around 700 miles have been recorded at short intervals since 1955.

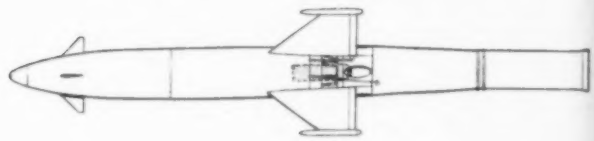
*Red Square, Moscow, on November 7: from the left, surface-to-surface weapons which we have called "Types IV, III, II and I."*

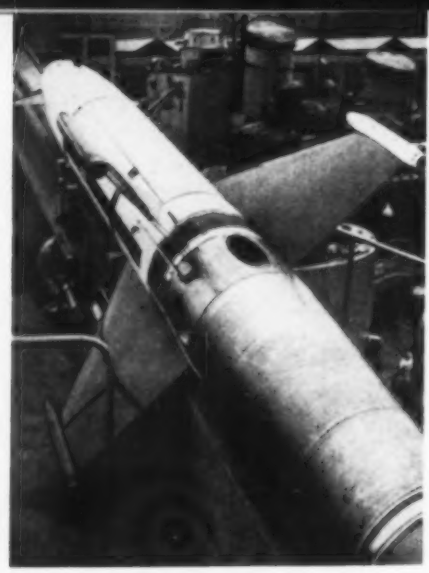
**MISSILES 1957 . . .**



**Robot 304** Air-to-surface. Internal sustainer, presumably a solid rocket. Estimated dimensions: length, 14ft 6in; span of wing, 6ft 6in; estimated weight, more than 1,000 lb. Speed is probably about Mach 1 and the range at least 5,000 yd.

**Robot 315** Surface-to-surface (naval). Four internal solid boost motors, pulsejet for cruise propulsion. Length, about 22ft; span of wing cruciform, about 8ft; launching weight, over 3,000 lb; cruising speed, probably about 550 m.p.h.





*Robot Type 315 on its firing ramp aboard the destroyer Smaland.*

## Sweden

UNTIL one month ago virtually nothing worthwhile could be said of Sweden's missile programmes, but on November 4 two of the longest-established "Robots" were publicly revealed. These two weapons are described below. Most of the guided-weapon research has in the past been undertaken by the Guided Weapons Bureau; in the future, however, the aircraft industry (in particular the Saab Aircraft Co.) will handle the major part of the work.

**Robot 304** This very effective air-to-surface weapon was developed by the Robotbyran (Guided Weapons Bureau) in association with the F.O.A. (Services Research Establishment) and other organizations. Experience was gained with the experimental Type 302, which was first fired from a T 18B aircraft in 1948.

The requirement for the new tactical attack weapon was issued in the autumn of 1949. Project work began in March of the following year and a full-scale airframe was flown in the spring of 1954. The first complete 304 was fired in February 1955 from a Saab-29. As the drawing indicates, the weapon has cruciform nose controls and a rear-mounted wing with a hinged trailing edge and twin fixed fins. Propulsion in operational 304s is presumably provided by an internal rocket sustainer (the parachute-recovered training examples so far seen have no evidence of propulsion), and all-weather guidance (almost certainly radio command from the launching aircraft) is fitted. Performance details are restricted and those published beneath the drawing are estimates. Maj-Gen. Lennart Peyron, Air Force Chief of Staff, has described the 304 as the best weapon system available; he recently said that preparations already in hand to receive it include storage facilities and personnel training. The weapon has undergone intensive testing, mainly by the experimental establishment (Fc) at Malmslätt. Its principal carrier will be the Saab-32 Lansen, which has a 304 pylon beneath each wing. The price, currently about 100,000 Kr (£6,900), will fall considerably in production.

**Robot 315** Clearly employing a body, guidance system and warhead very similar to that of the Type 304, the 315 is a surface-to-surface bombardment missile of the Royal Swedish Navy. The basic requirement was formulated eleven years ago and in the autumn of 1946 an intermediate development prototype designated Type 310 was test fired. Actual project-work on the 315 began in January 1949; a representative airframe was fired in July 1953 and the first complete 315 weapon was launched in January 1954.

Unlike the 304, the Type 315 has cruciform wings. Launching is effected from a fairly lengthy ramp under the thrust of four inbuilt solid boost rocket motors, the nozzles of which point outwards at some 20 deg from the body, in line with the trailing edges of the wings. Cruise propulsion is effected by a noteworthy type of intermittent pulsejet, fed from an annular intake grill close to the rocket nozzles and surrounded by a large-diameter pipe which apparently induces additional air. Nothing has been revealed regarding the mechanical design of this pulsejet nor of its fuel. The overall configuration of Robot 315 is unique, and at first sight seems unduly complex.

Like Robot 304, the 315 was developed at the Robotbyran, in collaboration with other agencies. Commodore Sven Rosenberg, chief of Robotbyran, recently stated that 315's development had been complicated by the fact that it has two propulsion systems—a sentence which may hide a multitude of dashed hopes. Most test firing has been done from the ground-test establishment at Karlsborg, on Lake Vaettern. Two operational destroyers, *Halland* and *Smaland*, are equipped with the weapon, and the former ship conducted her first firing trials in April 1955. Robot 315 has all-weather guidance, and the complete system is coming into production at the Air Force Central Workshops, assisted by civilian subcontractors. If reliable, it should be a formidable weapon.

## Switzerland

### *SURFACE-TO-AIR*

**Contraves-Oerlikon Type 56** For about ten years Contraves, Ltd., together with the Armament Division of the Oerlikon Machine Tool Works, Bührle and Co., of Zurich, have been almost unique in having developed guided weapons on an entirely private-enterprise basis. Today they are able to offer a fully developed surface-to-air missile system for sale "over the counter." Three years ago the Type 54 missile was evolved, with a liquid-propellant motor delivering a thrust of 2,200 lb. No boost was employed. Weighing 820 lb, the missile was a beam-rider with a speed of 852 m.p.h. and a maximum operating height of 50,000ft. Early in 1952 the U.S.A.F. bought 25 missiles of a previous type and, as the MX-1868, evaluated them at Holloman.

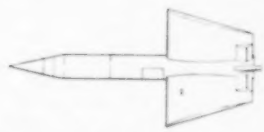
The present Type RSC-J has the same dimensions as the Type 54 but is more refined and incorporates a great number of detail improvements It is used at present as a training missile for the Italian Air Force on the firing range of Salto di Quirra on Sardinia. Like its predecessor, the Type 54 missile, it has a body made from wrapped light-alloy tubing with Araldite bonding, the wings being of sandwich construction. The wings, which are now of delta form, are arranged to slide axially to compensate for changes in c.g. and c.p. during flight; control is effected by a tail cruciform, and at low speeds by the swivelling combustion chamber. Fuel is kerosine, mixed with WFNA (nitric acid) with ignition by a hypergolic spray of xylidine and tri-athyl amine; feed is by nitrogen pressure from a 4,267 lb/sq in bottle. The ogive nose of the present training missile houses the electronic units and a recovery system. The tactical missile carries a warhead of 88 lb with a proximity fuze.

Launching, without boost, is possible at any angle from 90 deg down to about 20. After gathering in a wide beam the missile is centred in a fine guiding beam (see our issue of January 7, 1955 for system details) and describes a curve of pursuit. Motor burn-out of the tactical missile takes place after 45 sec at Mach 2.4, and the combat altitude limits are 10,000ft to 66,000ft. The missile is fired from a twin launcher and a tactical A.A. battery comprises six of these. Each battery is equipped with a target-tracking radar which controls the beam transmitter. All units are mobile and the sustained battery rate of fire can reach 12 rounds per minute. Training rounds are equipped with a complete recovery system. After a predetermined time the missile breaks in half forward of the wings, each portion being recovered by parachute.

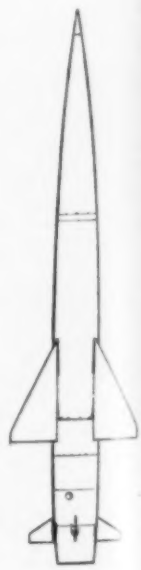
### *SURFACE-TO-SURFACE*

**Cobra IV** Since 1946 the Oerlikon Group have been developing simple anti-tank weapons embodying wire control similar to that used in the German X-7. One of the first examples to be publicly revealed is the Cobra IV, which is a joint development by Contraves-Oerlikon and Bölkow, the latter company conducting research at the Luftfahrtenwicklungen, Stuttgart. The design of the weapon closely parallels that of the French S.S.10, and the performance is similar.

(*This review continues on page 893, after photogravure section of feature articles.*)



**C.O.B. Cobra IV** Surface-to-surface. Solid sustainer motor. Length, about 34in; span, about 30in; firing weight, of the order of 24 lb; flight speed, about 180 m.p.h.; maximum range, about 1,500 yd.



**Contraves-Oerlikon RSC-J Model 56** Surface-to-air. Liquid-propellant sustainer motor, no boost. Length, 20ft; body diameter, 16in; wing span, 54in; firing weight, 820 lb; burn-out speed Mach 2.4 (Mach 1.8 for training missile).

**FIRESTREAK** — in production
for the Royal Air Force and the Royal Navy.

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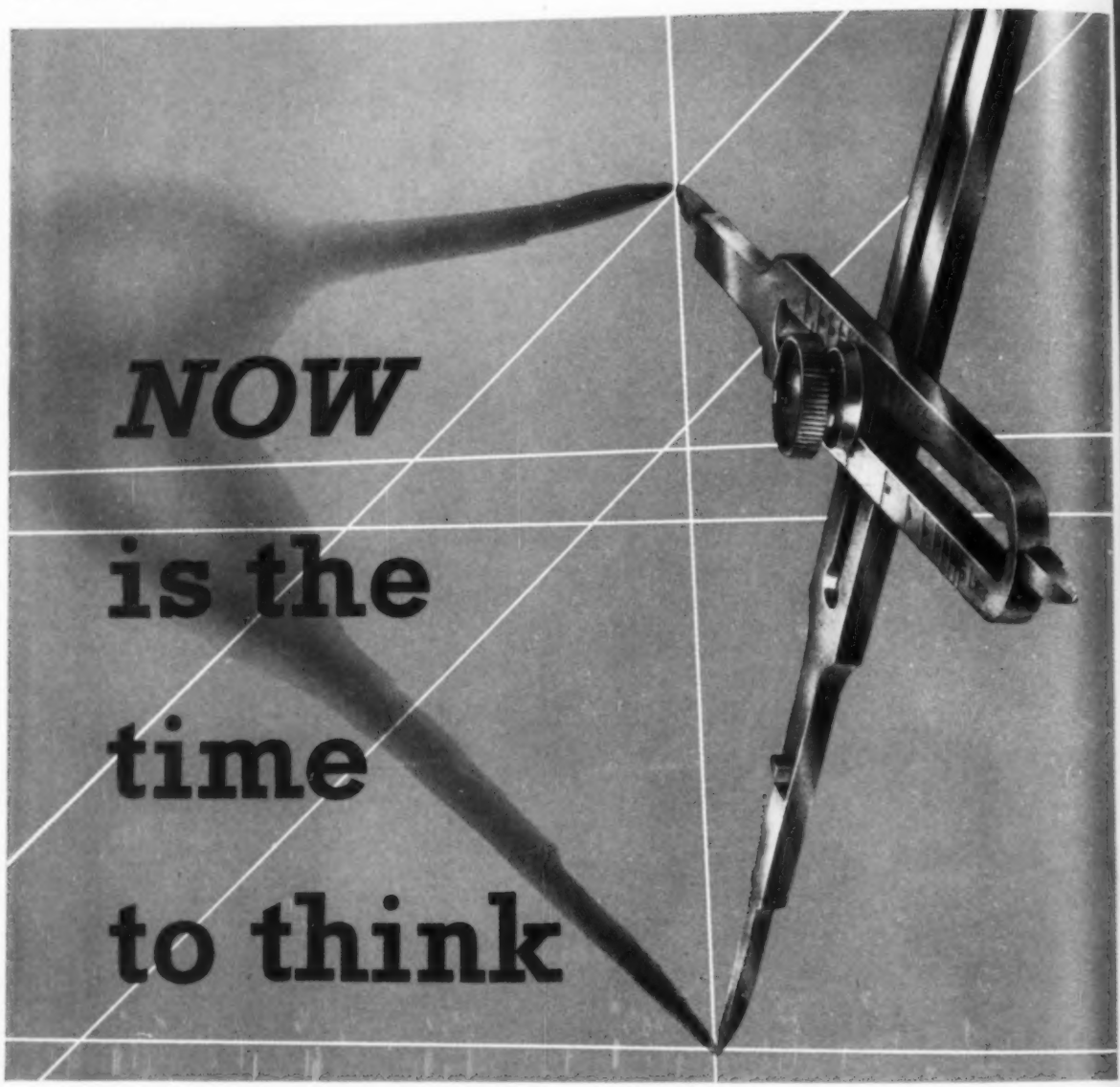


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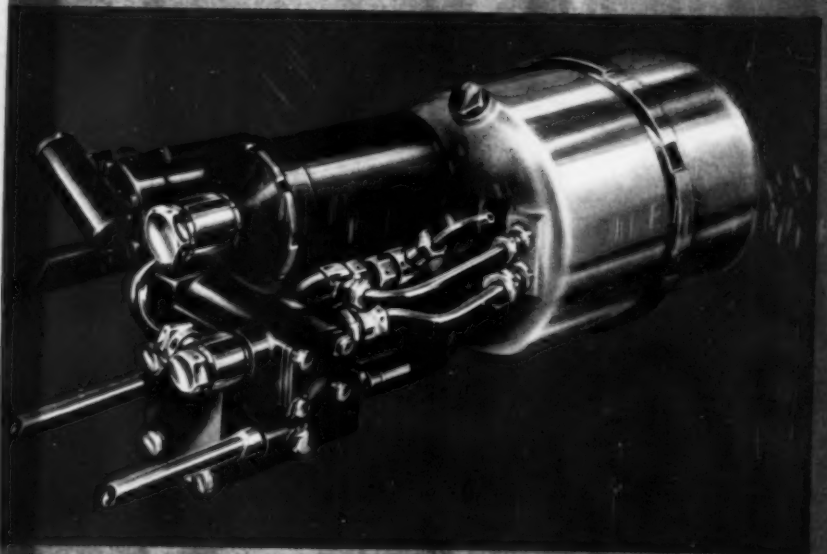

**Plessey** **Guided Weapon Power Pack**

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# THE SEASLUG

The A.W.A. Seaslug is the Royal Navy's first ship-to-air missile. Powered by a sustainer motor and four boosts, the Seaslug engages bombers at any height up to the maximum at which modern aircraft can fly. It is fired at individual aircraft selected by long-range radar and the firing crew is far smaller than the crew of a gun turret in a major warship.

The first ships of the Royal Navy to be equipped with the Seaslug are four Guided Weapon 'Daring' class ships which are on order. The trial ship, H.M.S. "Girdle Ness", is now in service and has already carried out many successful firings at sea. The Seaslug was developed by the Ministry of Supply and has been designed and constructed by Sir W. G. Armstrong Whitworth Aircraft Ltd., pioneers in guided missiles.

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD., BAGINTON, COVENTRY

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# The "Ultimate Weapon": A Layman's Guide to Some Problems of its Operation

SINCE our 1956 review of the world's missiles the whole field of guided-weapon technology has advanced rapidly and on a broad front. In no field has this advance been more spectacular than in that of long-range ballistic missiles, which in the past twelve months have emerged from being shadowy paper projects to a series of thunderous metal cylinders.

This is not to suggest that any of these weapons are as yet sufficiently advanced to be used operationally; in fact, as far as the Western world—by which we mean the U.S.A.—is concerned, none of these fearful devices could begin to act as a "deterrent" for at least a year. It is, however, appropriate at this time to present a series of pictures of some of the better-known ballistic weapons, and to comment on the more intractable problems which they pose.

Any long-range ballistic weapon consists, first and foremost, of a cylindrical airframe, designed to stand upright on its base and rise vertically. At the bottom of the device is a large rocket motor, which usually consists of a combustion chamber and nozzle assembly fed with liquid propellants stored in tanks occupying the major part of the body of the weapon. Typical propellants are liquid oxygen and kerosine, in an approximate ratio of 3:2. When the valves in the feed-pipes are opened the propellants tend to run down into the rocket chamber under gravity; but they are assisted on their way by pumps driven by a turbine energized by a steam-generator or by the propellants themselves. At full thrust the turbopump can deliver a flow which may be as great as half a ton per second. The rocket chamber itself may have an internal temperature of about 6,000 deg F and a pressure of well over 500 lb/sq in; moreover, in an intercontinental missile, the chamber has to keep operating for several minutes. The total horse-power produced may, at the point of burn-out (i.e., when the motor ceases to operate), be as much as twenty million.

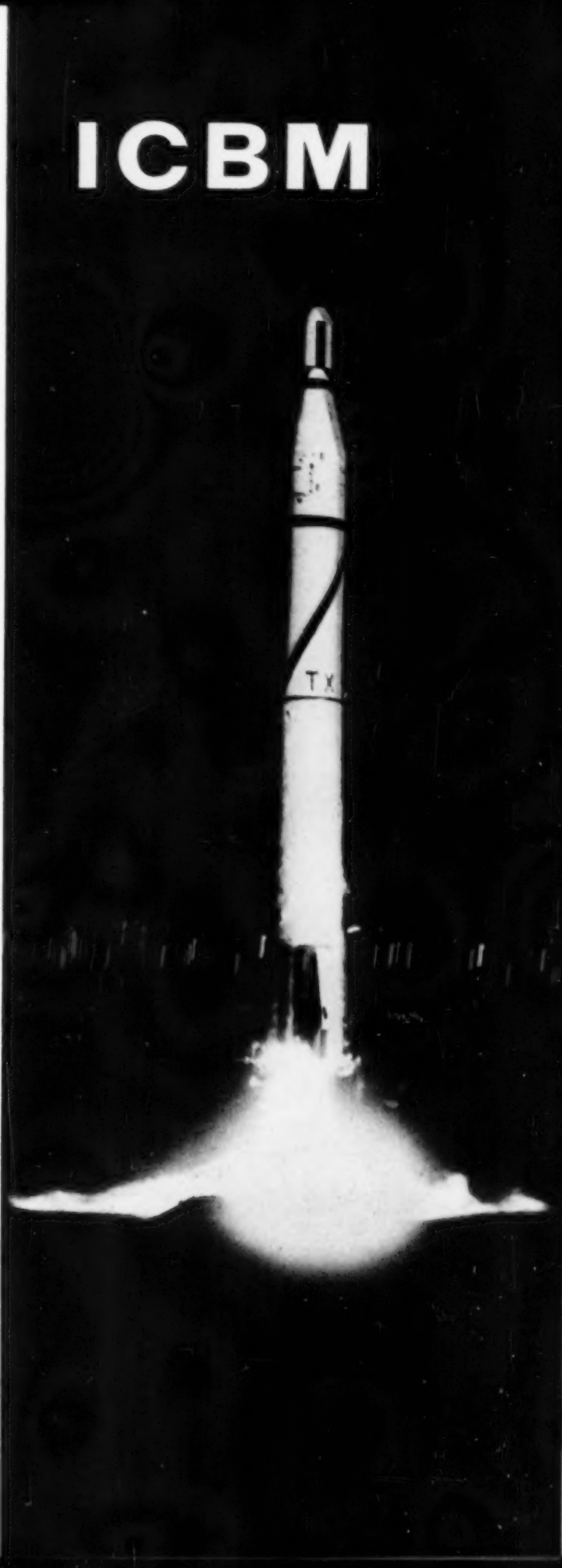
So much for propulsion. Having lifted the missile into the air one is next faced with the problem of controlling it, to ensure that it travels in the correct direction and eventually hits its target. But before anything can be done with even the most accurate missile it is necessary to know where the target is, or—in the case of a moving target—where it will be when the missile reaches it. The only exception to this rule occurs in the case of a fully homing missile, either with a "passive system" such as sensitivity to the infra-red (heat) rays emitted by the target or a fully active radar in which the missile actually seeks the target with its own self-contained electronic devices.

But neither of these systems can reasonably be used to guide a ballistic weapon which climbs 800 miles and plunges down again to a target on the other side of the globe. It is a diverting exercise to try to devise methods by which an ICBM (intercontinental ballistic missile) might, at some future date, be persuaded to pick out a previously chosen target and home on to it. The problems soon begin to look insurmountable.

It follows that the best that tens of thousands of guidance specialists can do is to develop systems which can establish the weapon on the right trajectory at the *start* of its flight, and thereafter leave it to itself. It is this free-falling characteristic which puts the word "ballistic" into the ICBM designation. A logical outcome of this fact is that, when an ICBM is fired, it must contain knowledge of the exact position of its target. Curiously enough, even the determination of this position poses problems. Very few people know exactly where Moscow lies in relation to New York, or *vice versa*; and it may be that the research now going on under International Geophysical Year auspices will enable a survey of our whole globe—as distinct from separate portions of it—to be made. This is an ideal example of the manner in which political considerations misuse the information gained when nations co-operate in increasing our store of knowledge.

Actually, the explosive power of what is called a "first-class" warhead—a "yield" equivalent to perhaps twenty million tons of T.N.T.—is so tremendous that, even if it misses its target by several miles, the lack of accuracy is of little more than academic interest—especially to those at the receiving end. But even an accuracy of a couple of miles at a range three thousand times as great is no mean achievement, particularly when the entire "intelligence" to achieve this accuracy has to be contained in the missile when it leaves the ground.

One method of navigation that can be employed by missiles




***An IRBM (intermediate-range ballistic missile) test vehicle of the U.S. Army—a modified Chrysler-built Redstone missile carrying an experimental nose-cone and re-entry body similar to that recently displayed by President Eisenhower. It was launched at Patrick A.F.B., Florida.***

## ICBM . . .

*A Douglas Thor IRBM of the U.S. Air Force shortly after leaving its firing pad at the Missile Test Center, Patrick A.F.B., Florida.*

which, like a bomber, "cruise" on the lift of a wing is automatic tracking of the stars, with subsequent computation of the course to steer to reach a previously programmed destination. It is also possible to accomplish much with radar systems of enormous power, and electronic systems pouring out millions of watts of radio energy may form part of some American ballistic-weapon systems. Such radars can "see" the outward-bound missile for a surprisingly great proportion of its flight, since the trajectory soon reaches heights hundreds of miles above the earth. During this phase the radar beam can keep the missile precisely on its proper trajectory until contact is finally lost or the rocket "cut-off" point is reached. But neither of these arrangements can compare with the inertial system, which is wholly self-contained (and therefore, one supposes, immune from counter measures) and quite beautiful in its scientific perfection.

*Flight* offered a valuable basic explanation of inertial systems in a special issue on April 12 this year. It is not now proposed to recount any of this, but merely to state that an inertial system measures the acceleration to which it is subjected. A man in a lift could, if he were clever enough, always know which floor he was on solely with the aid of a weighted spring-balance (to measure vertical acceleration) and a stop-watch (to provide the time factor and thus enable elementary integral calculus to be used to determine the distance travelled). Carrying this idea further, it is possible to visualize a self-contained device capable of measuring acceleration along all three axes (up and down, left and right, fore and aft), so as to determine the position of a flying vehicle. Such devices have been developed for long-range ballistic missiles, capable of detecting to within 0.00015g (the acceleration of a car taking 2 hr 30 min to reach 30 m.p.h. from rest).

To look at a really complete inertial guidance system one would have to go to the U.S.A. (and be armed with a security clearance). The device would doubtless impress a casual observer, and yet for complexity it would be put to shame by, say, a telephone exchange. What would certainly not be apparent would be the accuracy—and hence cost—affecting almost all the interior parts. For example, the gyros used to establish the references for the basic "inertial platform" cannot be allowed to drift more than about 0.001 deg per hour, and so are manufactured more carefully than any other part of any weapon—possibly with as much precision as anything else yet attempted by man.

One maker of such gyros (Minneapolis-Honeywell) surveyed more than 20 sites throughout the U.S.A. before they settled on one at St. Petersburg, Florida, where they now make inertial-quality gyros. Here the vibration in the earth's crust is not more than ten-millionths of an inch, reduced inside the plant to a few micro-inches, an acceptable figure. Another inertial-system plant can be entered only through a succession of ante-rooms, each with an air-lock, in the course of which a visitor has to replace his outer clothing with all-enveloping nylon, empty his pockets and endure a pounding with air blasts and other devices to ensure that he is not the harbinger of a single speck of dust or extraneous material. Inside the plant pencils are taboo, as is paper, for both make dust. Special pens are used in the drawing office, working on vinyl plastic sheets. And somewhere from a small door flows a procession of gyros, each small enough to fit a raincoat pocket but costing tens of thousands of dollars.

One could perhaps argue that this fetish for cleanliness and care is nonsensical, and that, when the resulting missile is standing in the pouring rain on a distant firing pad it will have to work in far less accommodating conditions. But it must be remembered that the ICBM is no ordinary weapon, and probably will always be given special treatment. Its delicate parts will continue to be cosseted by white-coated specialists; the odd million dollars will never stand in the way of an improvement in the system, to increase reliability or remove a possible source of human error; and, except in the direst emergency, nobody will mind very much if the firing takes place five minutes, or five hours, later than it was supposed to. In such matters the big ballistic weapon differs completely from any other missile system.

When the inertial platform is built into the missile guidance system it is coupled up with a maze of synchros, servos, electronic computers (usually digital) and other paraphernalia, so that the basic sensing of acceleration can be constantly compared with the desired acceleration and corrections made to keep the missile on the right trajectory. For the first few seconds of flight the stabilization of a ballistic missile may be assisted by tail fins, or a flared skirt, or movable aerodynamic rudders. Soon, however, the weapon is far above anything that an aerodynamicist would call an atmosphere, so that fins or rudders are useless. The guidance and control system then governs the flight of the missile by pivoting the chamber of its engine (as a drawing shows). This is reminiscent of steering an outboard-motor boat; but whereas the boat is subject to hydrodynamic loads, and thus can readily alter its heading, the ICBM in the remote ionosphere is subject to only two forces—rocket thrust and gravity. Quite possibly the axis of the body may not alter, so that the weapon may eventually fly sideways, there

being no air drag to confer what is called "weathercock stability"; but the only factors which matter to the trajectory are the thrust-line of the engine, the weight and the overall acceleration.

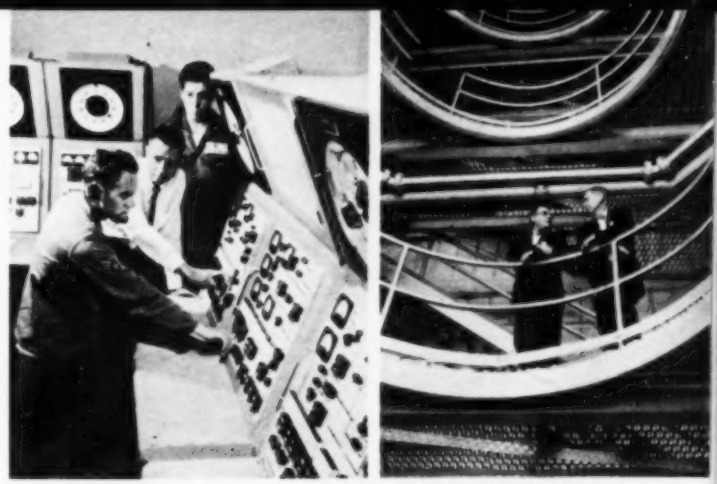
Somewhere along its journey the missile will require no further thrust, and the feed to the engine must then be cut off with very great accuracy (a delay of as little as one second may cause the target to be overshot by three miles or more). The job of the biggest part of the missile, the tankage and motor used for propulsion, is now completed. Accordingly it may well be discarded, and the remaining propellants—along with the airframe and motor—allowed to burn up as a result of the intense aerodynamic heating experienced by the body when it descends into the atmosphere—say, at a height from 100 down to 50 miles. No way of preventing this intense heating or slowing the missile down has yet been found; forward-facing rockets have been exhaustively investigated, as have large air brakes or parachutes, along with cooling systems whereby tons of water are forced through the nose; but each new suggestion has proved either unworkable or practicable only at the expense of ruining the performance of the weapon.

We are, therefore, left with a warhead moving at some 15,000 m.p.h. along a gently climbing trajectory, right outside the last vestiges of any real atmosphere. On it goes, slowing down very gently and climbing less and less steeply, until finally it reaches the zenith of its trajectory—technically called the apogee—800 miles from the nearest point of the Earth's surface beneath it. It seems almost infinitely lonely, a tiny package made by human hands and bearing wiring diagrams and instructions intelligible to its operators; were it to contain a sentient being he would feel utterly remote from the Earth, despite his knowledge that he would reach it in a mere fifteen minutes' time.

Should our imagined ICBM have been fired in anger the target area may well be expecting to receive it, and super-powerful radars will detect the intruder when it still has over one thousand miles to go. But the warhead has quite a hard enough task ahead without interference from defensive devices. Already, it is beginning to curve down again towards the earth, maintaining its enormous speed in a manner which for ponderous persistence is quite frightening. In fact it actually moves faster and faster, and there is nothing at hand to stop it—just infinite miles of outer space. Soon the space becomes less empty; increasing amounts of dust and gas are encountered and the resulting drag slowly swings the re-entry body round until it is falling nose-first, like a bomb. And in a few seconds the skin becomes warm, and then hot, and then glows a dull red. The red becomes brighter, and the whole structure would very soon vaporize—were it not for two factors, each the result of literally millions of hours of work by an army of scientists: the nose is blunt and very smooth, and the whole assembly is very carefully constructed from unusual materials.

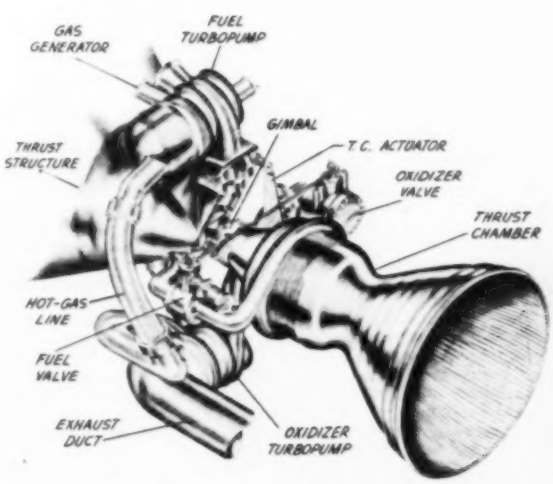
It may seem strange to have a blunt nose on the fastest thing made by man, but the American National Advisory Committee for Aeronautics, and Mr. H. Julian Allen in particular, discovered that when a device such as a ballistic-missile nose-cone re-enters the atmosphere it can withstand the arduous mechanical and thermal conditions better if its nose is given a fair radius. This shape rejects more than 90 per cent of the heat back into the surrounding air. Nevertheless, the nose-cone and what is called the re-entry body (housing the warhead) still get very hot, and their construction makes greater demands than does that of any piloted aircraft. Moreover, the plummeting object leaves behind it a trail of ionized gas, readily detectable by radar and yet completely enveloping the nose-cone itself, further complicating the proceedings.

When the nose-cone is down to 50,000ft it has less than three seconds to go. Final arrival on target is something of an anti-climax, unless the warhead happens to be armed; and in any case, one big bang is much like another. W. T. G.



*Left, checking possible human error on the Convair Atlas ICBM fuel-transfer test console. Right, steel platforms in an Atlas test facility at Convair's San Diego plant. Seen are Mortimer Rosenbaum, chief engineer, and J. R. Dempsey, manager of Convair-Astronautics.*

*A thrust unit for a Chrysler Redstone of the U.S. Army, suspended from a 25-ton crane, is lowered into place to be joined to the forepart of the missile.*




*Above, a rocket engine assembly employing separately-driven propellant pumps—a drawing by the Aerojet-General Corporation. Right, an Atlas en route from San Diego to Patrick A.F.B.—a picture which, on close study, gives more cause for reflection than any other in this issue.*

# Selling Guided Weapons

## With Particular Reference to Ground-to-Air Systems

*In these three pictures are seen English Electric Thunderbirds immediately after launching and — in two photographs from Woomera — homing on to a Jindivik target aircraft and, finally, completing what appears to be a perfect interception. The Thunderbird had no warhead; the explosion is from the fuel of missile and target.*

By L. H. BEDFORD, C.B.E., M.A., B.Sc., and E. L. BEVERLEY, D.F.C.*

THE cost of developing complete guided weapons systems is now so high that, from the viewpoints of both the contractors and the country as a whole, it is essential that each fully developed system is ordered in substantial quantities, if there is to be any possibility of recouping this great expenditure in order to re-employ it for future developments. It is ironic that, because of the very considerable increase in lethality provided by guided weapons, the quantities required are not by any means as large as most people might imagine. It follows that, if these projects are to be commercial propositions—and to lessen the burden on the British taxpayer—it is essential for contractors to find overseas markets to supplement their sales to the British fighting services.

In such selling operations it is our general experience that most overseas customers are primarily interested in "systems" and not in the individual components. Since a complete guided weapons system may include a whole variety of equipment—from the ground radar down to a comprehensive kit of mechanical-handling gear—considerable effort is required to ensure that the overseas customer is fully aware of the many components required to make up a complete system.

Few nations have any previous service experience of guided weapons and, therefore, the task of selling these weapons is often a matter of education, of explaining the British concept of their development and operation and of revealing the tremendous range of equipment and general facilities which have been built up in the United Kingdom.

Countries which would very likely be involved in any future major war are naturally concerned at the basic advances in the offensive side of warfare which have been made in the last dozen years. They are aware of the enormous increase in striking power which occurred in 1945 with the atomic (fission) bomb, followed seven years later by the further step of a similar order with the hydrogen (fusion) bomb. Aircraft speeds have been steadily increasing since the sound barrier was crossed in 1947, and radar-echoing areas have been decreasing. Radio warfare—a vast subject —has made its own advances which may seriously handicap defences. These and other facts are well known to countries which are now considering the adoption of guided weapons, but techniques on the defensive side have certainly not stood still. Overseas customers naturally wish to buy a weapon system which incorporates all the latest advances in defence technique.

In order to show how these techniques have been developed it is necessary to invite technical delegations from the various countries to England and show them in detail how our present projects have been developed and the extent of the resources we have deployed. They can thus see the extent of the tremendous effort required to move from 50 per cent reliability under optimum conditions and using our contractors' skilled personnel to 90 per cent under operational conditions in the hands of Service personnel. They can see that the philosophy of missile development in terms of maximum effort on the ground is useful, and possibly essential, and that flight trials should not be used to prove a principle but rather to substantiate the results of ground proving, and that, in the limit, all flight testing should be purely confirmatory. They can see how and why we consider that the airworthiness of the various components should be established first on the ground and then *confirmed* in flight, and that to this end elaborate and comprehensive environmental test facilities are needed. They can also see the need for the flight of a number of test rounds in which the telemetry channels are mainly allocated to vibration measurement. There remains the by no means easy problem of interpreting this into a vibration-test specification, and the provision of the necessary equipment. This in turn involves the important decision as to the extent to which it is legitimate to break down the missile into sub-assemblies for vibration and impact test, equipment for the vibration of a missile *in toto* being somewhat formidable.

At the factories we can show these experts how it has been generally experienced with current types of weapons that the designs laid down for development, though conceived in good faith as the basis of operational weapons, do not in fact constitute good designs for Service employment. A major decision has to be made either to "engineer" the development design or to incorporate the development experience into a completely new *ab initio* Service weapon. If the latter decision is taken, the salient points in the new design are likely to be its ease of assembly and break-down, the accessibility of all parts in a working condition, servicing by replacement, and packaging in sub-assemblies. Corresponding requirements for the ground equipment are suitable handling devices, overall test facilities of a "go/no-go" character, and facilities for theoretically infinitely long storage and check-out of missiles on the launchers.

Naturally, the foreign purchaser's main interest is in the type of defence which the system can provide and how much it will cost. Before these questions can be answered, the contractor is involved in a very considerable amount of preparatory work. In the first place he must reach a clear understanding with the foreign country what the hostile threat is likely to be at the time of the installation of the equipment, both in numbers and type of aircraft, height, speed, echoing area and types of bombs carried. Then there must be an agreement upon which areas must be defended, and whether the defence should be an all-round one or restricted to particular sectors. It is probable that the country concerned already has some early-warning or tactical-control radar which it wishes to continue to utilize in the guided weapons era, and this must also be introduced into the calculations. For the most part, potential customers are developing defence systems which are based on British and American practice, and manufacturers have therefore designed their weapons to fit into these patterns.

With all this information, and the performance information of his own system, the weapon contractor must then get down to detailed calculations requiring the use of computer services in order to work out a suggested deployment to meet the particular

*Respectively Chief Engineer and Commercial Manager, Guided Weapon Division, English Electric Co., Ltd.*

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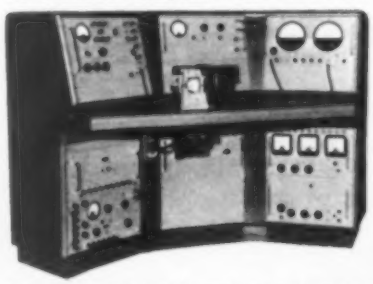

completely redesigned, and now has improved accuracy of amplitude and phase indication at low frequencies.

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## SELLING GUIDED WEAPONS . . .

case. Initially these problems require a great deal of mathematical effort, but as more experience is gained it is possible to develop particular techniques which tend to shorten the time involved. A set of working rules can be formulated to control such parameters as the extent of supporting fire, the location of the tactical control centre and the siting of the fire units. From these rules, it is possible to calculate the effectiveness of a particular deployment against the particular types of threat that are being posed. It is generally the case that there is one major and a number of minor threats which have to be met. Finally it is necessary to list all the equipment required for such a deployment, and then to price it.

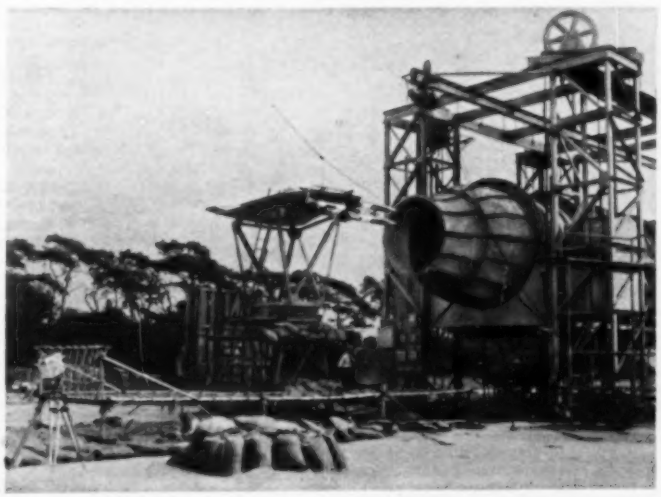
Negotiations of this sort—which may last for many months—are hampered by questions of Security, and contractors rarely have a completely free hand to execute their sales campaign. The British Services are, quite correctly, concerned that the details of vital future weapons should not fall into the hands of potential enemies. On the other hand, there is considerable pressure for equipping our allies with the best weapons available and building up a common defensive system which, if based on British weapons, will secure essential exports to aid our balance of trade. Between these conflicting views the contractor has to tread a delicate path if he is to conduct a successful sales campaign against the increasing American competition which is now being experienced. This is quite literally "education," and not mere sales-talk.

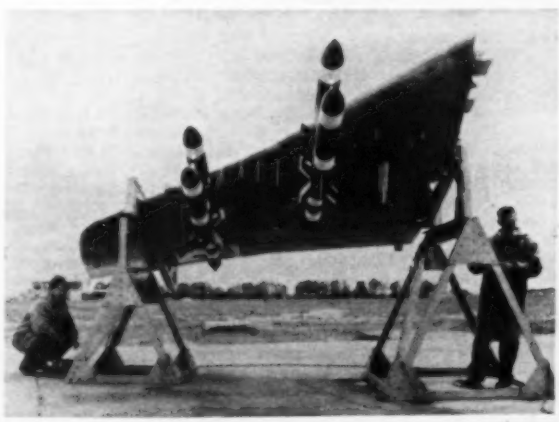
# RAIN, HAIL, BLOW OR SNOW

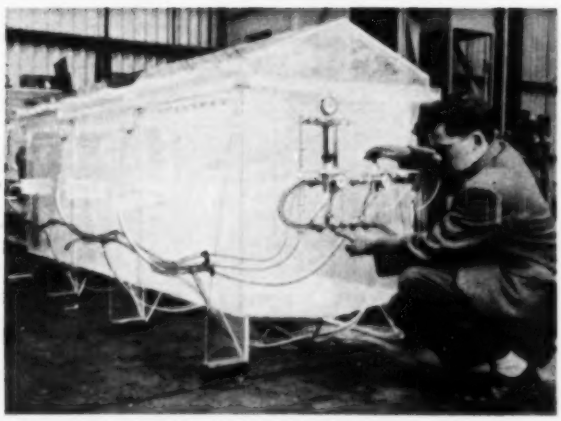
## Proving the Fairey Fireflash

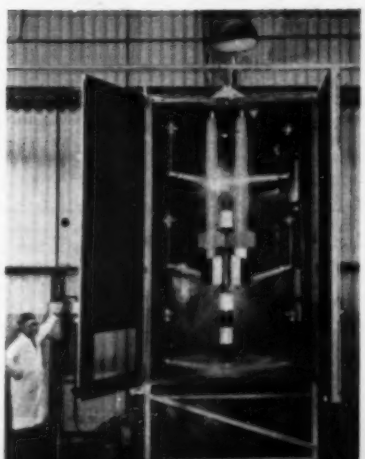
IN the article concluded above the point is made that tremendous effort is required to take an apparently "developed" weapon and bring it to the stage where it will perform reliably under genuine Service conditions. These photographs from the weapon division of the Fairey Aviation Company show typical aspects of the work which preceded the final clearance of the Fireflash air-to-air weapon for Royal Air Force service.

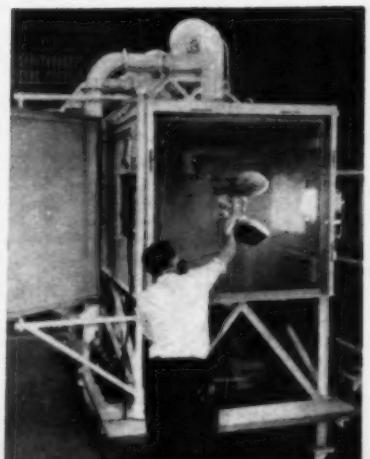
On the right the big blower tunnel at Boscombe Down is being used to check the jettison characteristics of an early version of Fireflash. The next two photographs show preparations for a static firing from a Swift wing (to prove the wing against rocket blast) and the testing of weapon components in a Perspex chamber which can be filled with fine mist, acid, alkaline or salt-laden air. The bottom three illustrations show the electrical components of Fireflash being subjected to "driving rain"; a masked engineer checking the boost ignition and separation circuits after 30 minutes of simulated dust and sandstorm; and a round—it has acquired an ice coating—under test in the refrigeration chamber.











# Rockets for Research

## SCIENTIFIC EXPLORATION ON THE FRINGE OF SPACE

IN an issue of *Flight* devoted largely to recording the efforts of many countries to produce bigger, faster and more lethal means of airborne destruction, it is perhaps a refreshing change to consider some of the ways in which rockets and missiles can perform useful contributions to basic scientific knowledge on an international scale. With the International Geophysical Year programme in the background—and two orbiting Earth satellites very much in focus in the foreground—there is much of great interest to report in the field of research into the upper air.

The subject is wide and fascinating. It is simply exploration into the realm of space. The purpose of this exploration, for those who wish purposes to be stated, is to extend our basic scientific knowledge—to sound out the upper air. A sounding rocket blasts up to one hundred miles and telemeters data back for a few brief minutes: yesterday we used a lump of lead on a length of twine, swung outboard to sound the ocean-bed. The sea is now familiar, but the upper air is not.

We need to chart the upper air for a variety of reasons—simply to understand its structure better, to provide data for future manned interplanetary flight and, strangely perhaps, to find out more about our own planet Earth; its weather, its magnetism, and even its shape. The scope is wide, and this article cannot hope to cover the entire field in detail. We shall hope to indicate generally the kind of information that is sought and is provided by rockets and satellites, and to give examples of particular projects.

Temperature, density and pressure are obvious and basic properties to be measured directly, and it is only with rocket-borne equipment that a detailed knowledge of these properties at heights above the limit of balloon ascents has been obtained.

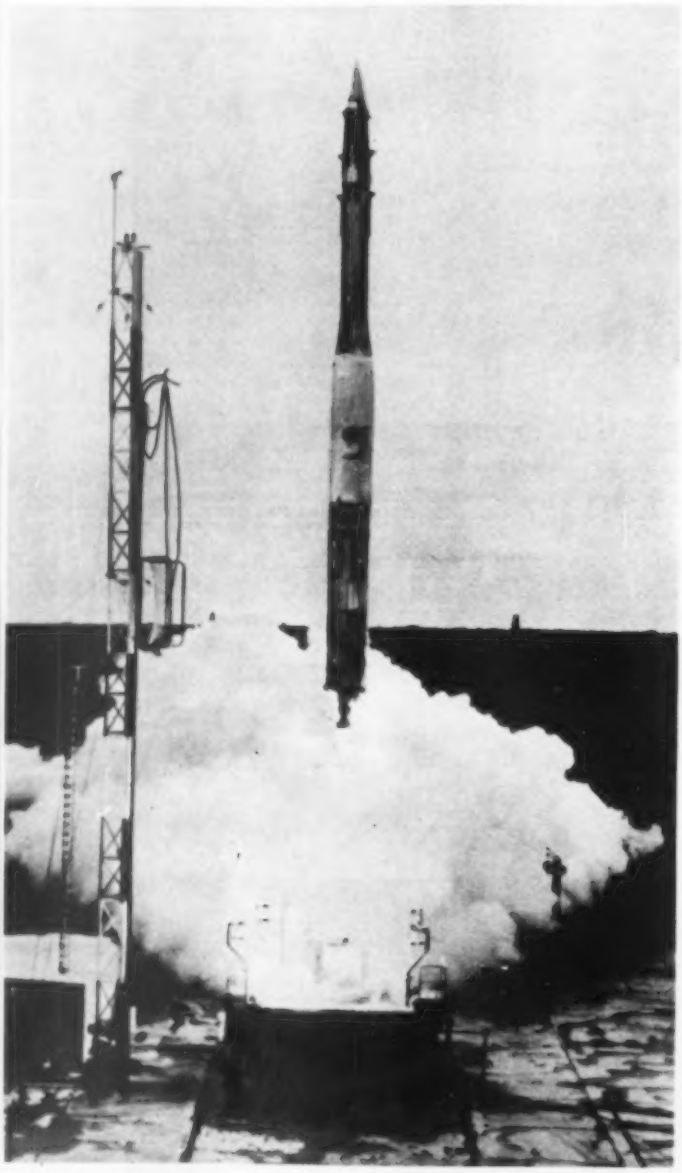
The peak altitude of the majority of sounding rockets occurs in the ionosphere, the "middle layer" of the atmosphere, which is an area of great interest. This region contains the ionised, or electrically charged D, E and F layers from which the reflection of ground radio signals has made possible very long-range transmissions. Ground-based methods of investigating many aspects of the ionosphere are difficult, while rocket sounding can provide much information.

Two most important subjects of study which demand high-altitude measurement are solar activity and cosmic radiation. A note of these two areas of investigation is included in the later references to Russian and U.S. satellite work. While the sounding-rocket technique gives good results in the study of the vertical variation of a quantity at a certain place and time, its limitations are the short duration (at most a few minutes) during which measurements can be made, and the fact that variations with time cannot be measured.

Night airglow can also be studied, using rocket-borne photometers. Other phenomena capable of investigation by rockets are the dynamo currents responsible for the quiet magnetic variations; disturbed magnetic variations (magnetic storms); and the extent and nature of the auroral zones.

Among other rocket experiments being carried out at present are the location of the optical horizon; determination of the distribution of ozone in the upper atmosphere; determination of ultra-violet fluorescences of upper atmosphere during auroras; measurement of the Earth's magnetic field, with such measurements used to locate ionospheric and auroral current flows; and the measurement of low-energy cosmic rays as a function of geomagnetic latitude, and correlation of intensity fluctuation with solar and magnetic phenomena.

For the extra expenditure of rocket power (and of accurate control) sufficient to establish a satellite in orbit, a great deal more information can be obtained than with any sounding rocket. Firstly, the satellite can carry its own measuring instruments and can telemeter the results to the ground until the batteries powering its transmitters run down. Secondly, ordinary continuous-wave radio signals from a satellite which, in an elliptical orbit, dips into the ionosphere to its perigree and out again to an apogee at 500-



*International Geophysical Year experiments include the establishment of Vanguard satellites in orbit by the U.S.A., and firings of Skylark upper-atmosphere rockets by Britain. The U.S. satellite programme was preceded by the recent test launching of the three-stage Vanguard rocket (left) at Cape Canaveral, Florida; the heading photograph shows a Skylark launch at Woomera, South Australia.*

1,000 miles, can be of enormous value in providing data on radio transmissions through the ionosphere. Thirdly, even when the satellite is silent it can be tracked visually and by radar, and its speed and exact orbit can give data for air density calculations, the forecasting of future orbits, and studies of the Earth's magnetism.

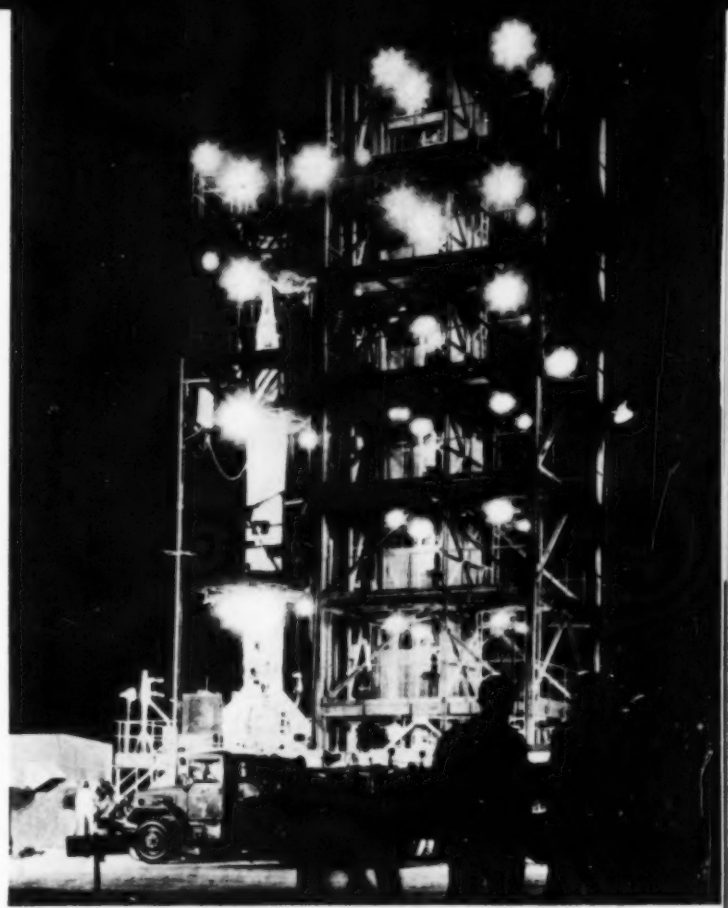
A comprehensive symposium on high-altitude and satellite rockets was held by the College of Aeronautics, the Royal Aeronautical Society and the British Interplanetary Society at Cranfield last July (reported in *Flight* of August 2) at which 12 papers were presented. Another general reference to satellite flight is the article *A New Realm of Flight* which appeared in *Flight* of October 18.

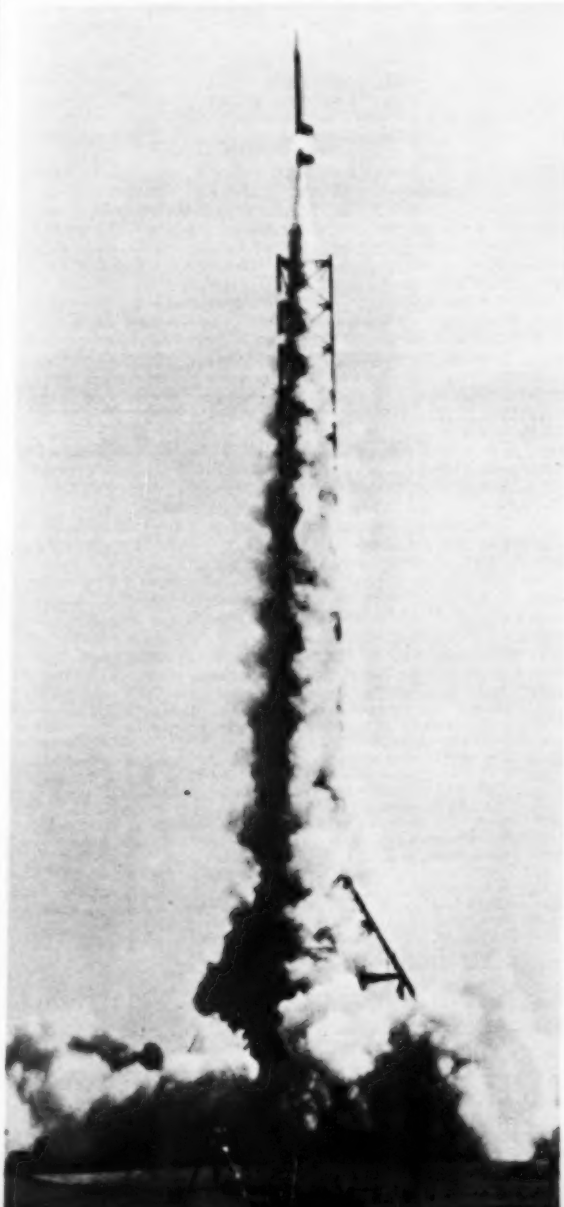
**Projects in the U.S.A.** The American programme of upper-atmosphere research by means of sounding rockets was begun in 1946 with the launching of the first ex-German V-2 rockets in the U.S.A. An important second step was to use the V-2 together with a small U.S. rocket, the WAC-Corporal, as a two-stage vehicle.

For many research purposes the V-2 was too large and the WAC-Corporal was too small, and there followed the first U.S. rocket to be specifically designed as an upper-air research vehicle. This was the liquid-propellant Aerobee, first fired in November 1947. Since then over 200 Aerobees have been launched and an improved version known as the Aerobee-Hi has been developed. Now well established as versatile upper-air vehicles, rockets of the Aerobee family are taking an important part in the I.G.Y.

Among recent experiments performed with this type was the firing of artificial meteors (aluminium pellets) from an Aerobee at a height of 54 miles over New Mexico on October 16; and the release of sodium vapour at between 80 and 100 miles to produce an ionized cloud with which to study the reflection of short-wave radio transmissions. The aluminium pellets were fired at speeds up to 40,000 m.p.h. (greater than escape velocity).

*Aerobee-Hi launch (below) from White Sands. Successor to the ubiquitous Aerobee, the Aerobee-Hi was used in the recent U.S. artificial-meteor experiment. The night scene (right) shows Viking rocket and launching tower at Patrick Air Force Base, Florida.*



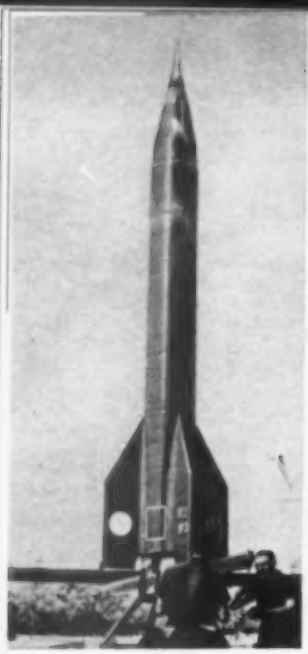


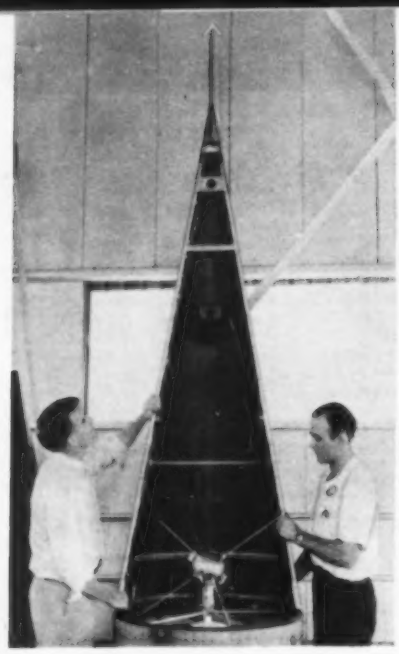
Other American sounding rockets include the Viking, a large V-2 replacement which, in an improved version, formed the basis for the first stage of the Vanguard satellite launching vehicle; and a variety of small and efficient rockets designed for economy and (in many cases) limited scientific purposes. The most important of these are listed in the table below.

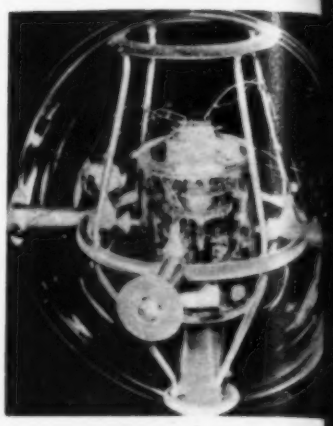
| Rocket | County | Stages | Altitude (miles) | Payload (lb) |
|---|---|---|---|---|
| Nike-Cajun ... ... | U.S.A. | 2 | 95 | 60 |
| Arcon ... ... ... | U.S.A. | 1 | 70 | 40 |
| Iris ... ... ... | U.S.A. | 2 | 200 | 100 |
| Terrapin ... ... | U.S.A. | 2 | 80 | 8 |
| Rockoon (balloon/Deacon) | U.S.A. | 1 | 50-70 | 20-30 |
| Rockaire (aircraft/Deacon) | U.S.A. | 1 | 100 | 40 |
| Farside rockoon ... ... | U.S.A. | 4 | 4,000 | 10 |
| Asp ... ... ... | U.S.A. | 1 | 40 | 25 |
| Aerobee ... ... ... | U.S.A. | 1 | 70 | 150 |
| Aerobee-Hi ... ... | U.S.A. | 1 | 122-165 | 120-200 |
| Spaerobee ... ... | U.S.A. | 2 | 350 | 40 |
| Skylark ... ... ... | Britain | 1 | 100 | 100-150 |
| Veronique ... ... | France | 1 | 84 | 130 |
| Kappa ... ... ... | Japan | 2 | 80 | 15 |

One typical moderate-performance sounding rocket is the Nike-Cajun, approximately 50 of which are to participate in the I.G.Y. programme. This is a high-altiude version of the Nike-Deacon, the Army's Nike booster being used as a first stage, and the Cajun second stage carrying a 50 lb payload of instruments to heights of about 10 miles. Among the Nike-Cajun I.G.Y experiments are the measurement of water-vapour distribution; total-field magnetometer readings and electron-density measurements in the E-region; cloud-structure studies by photography of the optical horizon; measurement of cosmic rays and auroral radiations; and measurements of X-rays during solar flares.

In general the trend in the U.S.A. over the past ten years has been a switch from the large rocket carrying extensive equipment for a variety of investigations, to the smaller rocket used for a more limited range of measurements on any one flight. From the V-2 payload of 2,000 lb, favour has turned to the small package weighing 50 or even 10 lb. By concentrating on less complex equipment, the chances of successful results are higher, and the small rocket can take advantage of assisted launching either by a large booster rocket or by "rockoon" or "rockaire" techniques.







***For left, French rocket Veronique, developed from German V.2. Left, the first U.S. test satellite (note rectangular ports for solar batteries) in position with half of phenolic asbestos nose cone. Right, a model of a full-size Vanguard satellite showing central instrumentation pack, mountings for antennae, and (mounted against shell) cells for recording solar radiation.***

## ROCKETS FOR RESEARCH . . .

The Rockoon consists of a small rocket such as a Deacon which is carried aloft by a high-altitude balloon (itself released from either ground base or ship) before firing. The most spectacular example of this was provided recently by the Project Farside rocket which is believed to have attained an altitude of no less than 4,000 miles after being launched from a balloon at about 20 miles above Eniwetok Atoll. The Farside rocket has ten solid-propellant motors mounted in four stages. Four Recruits form the first stage, a single Recruit the second stage, four Arrow II motors (used in the Asp sounding vehicle) the third, and a single Arrow II the fourth.

The same objective of gaining altitude plus mobility in launching lies behind the Rockair (Navy) and Rockaire (U.S.A.F.) projects. These involve airborne launching of the rocket from aircraft at about 35,000ft, the actual firing taking place as the aircraft pulls up into a vertical position prior to completing a loop. Navy research has included modifying a standard folding-fin aircraft rocket (basic cost $50) to accommodate a cosmic-ray counter and associated telemetry; the Air Force have used a special Rockaire rocket, powered by a standard Jato unit and carried under the wing of an F-86D. In the latter case a 40 lb payload launched at M = 0.8 at 35,000ft will reach about 45 miles.

Prior to the launching of the first Soviet sputnik, comprehensive advance details had been published concerning the U.S. satellite programme, Project Vanguard, and a description of the rocket vehicle and Vanguard satellite itself was included in *Flight's* report of the Cranfield conference in our issue of August 2. The main Vanguard experiments will relate to the firing (expected during 1958) of six 20-inch instrumented spheres weighing 21¼ lb each into orbits around the Earth. These will be preceded by smaller, simpler satellites 6.4 inches in diameter and 4 lb in weight, the first of which is scheduled to be launched during this month.

Instrumentation in the 20-inch satellites will include an ion-chamber unit (with associated electrometer circuit, solar battery used as an aspect photo-cell, magnetic memory circuits, orbital switch and resetting circuit) for the measurement of solar radiation; environmental instrumentation such as thermistors to measure temperature, evaporated resistance strips sensitive to erosion by meteors, impact microphones to count meteorites, and pressure gauges to detect punctures of hermetically sealed zones; and the Minitrack transmitter which not only provides the tracking source but also transmits the telemetered signals. Cosmic rays will be registered by means of a Geiger counter, 50 individual measurements per orbit being stored by a miniaturized magnetic tape recorder before being telemetered to the Minitrack stations.

In addition, the Earth's main magnetic field and ionospheric currents will be studied from measurements made by a Varian proton precession magnetometer. Meteorological experiments planned are the determination of the radiation balance of the Earth and atmosphere, and measurement of the distribution of the Earth's cloud cover. For the former, the temperature of small spheres mounted at the tips of the radio antennae will be monitored to deduce changes in radiant energy; and the cloud cover will be recorded by scanning the landscape below the satellite with infra-red photocells. (Here again storage of information is involved.)

**The British Skylark.** Britain's contribution to I.G.Y. high-altitude research by sounding rockets is centred on the Skylark rocket, designed by the Royal Aircraft Establishment and powered by a Raven solid-propellant motor giving a nominal thrust of 11,500 lb for about 30 seconds. It is designed to carry a payload of 100-150 lb to a height of 95 miles, and has a take-off weight of approximately 2,500 lb.

Skylark is 25ft in length, its conical nose and a cylindrical parallel section giving some 5 cu ft of useful payload space. The nose cone is made of stainless steel, and in some experiments a part of it will be jettisoned at high altitude by a spring mechanism. The nose cone and the parallel bay can be pressurized independently. In addition to equipment for specific tests, standard instrumentation includes a 465 Mc/s telemetry sender, Doppler transponder (104-208 Mc/s) and a 6 cm microwave beacon.

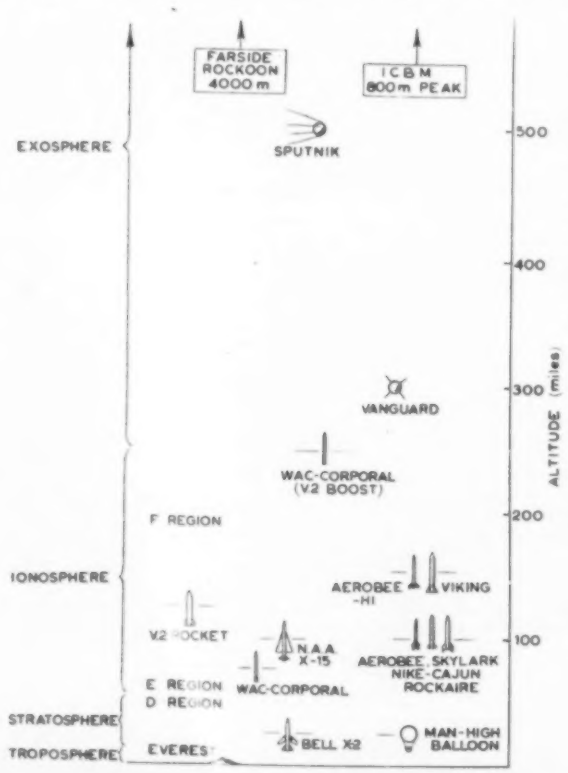
Six preliminary Skylark firings are being made at Woomera prior to the I.G.Y. experiments planned by the Gassiot Committee of the Royal Society, and a report of the fourth of these which, on November 13, attained a height of 83 miles, gives some interesting detail on the type of measurements being made by the Universities and the R.A.E. in this joint programme. Four special installations were carried on the flight:

(1) To measure atmospheric temperatures and high-altitude wind velocities: a series of 18 explosive grenades, ejected from the rocket at intervals above 100,000ft. Ground equipment included microphones to record the arrival of the sound-waves, ballistic cameras to record the position of the explosive flashes, and a detector to record the instant of each flash. This experiment was by University College, London.

(2) To measure winds at altitudes up to 50 miles: fourteen cartridges of "window" foil, released explosively in two clouds at heights above 100,000ft. These clouds were tracked by ground radar, and the experiment was devised by Imperial College, London.

(3) To measure ionospheric electron densities: a selection of the rocket nose, insulated to form a fixed-capacity condenser and included in a 5 Mc/s oscillatory circuit able to detect the presence of electrons in the ionosphere. The results in this experiment, which was devised by the University of Birmingham, were telemetered to the ground.

(*concluded on page 892*)




***Typical vehicles for upper-air research. Altitudes shown are approximate only; satellite orbits vary from over 1,000 to less than 200 miles. North American X-15 is designed for manned flight to 100 miles.***

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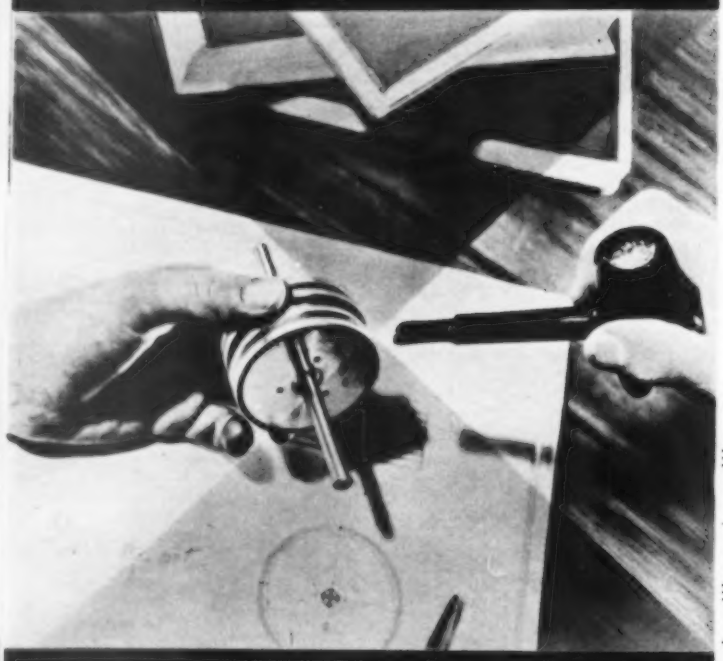

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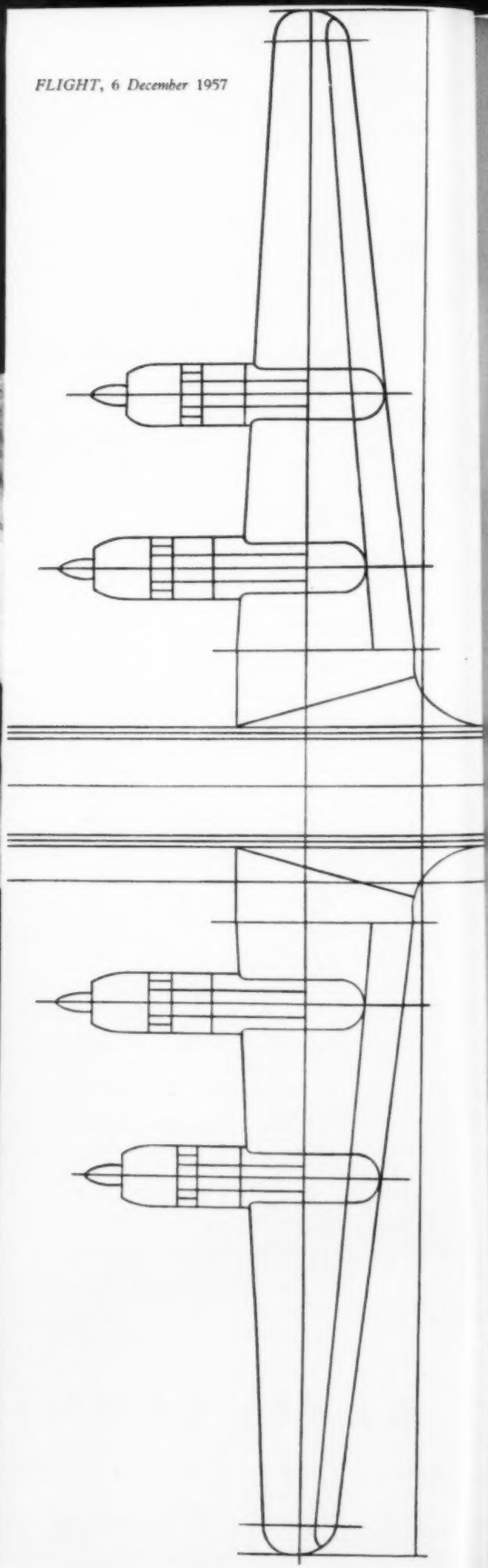


# The Law of Space

BY MICHAEL AARONSON

**DIRECTLY relevant to the use of rockets and missiles in exploring outer space is the formidable range of associated legal problems which, with the launching of the first artificial satellites, has suddenly been brought into sharp focus. Some of the implications of current developments in international airspace law are here discussed. The article was written before a recent lecture (reported overleaf) by an eminent American authority on air law, Professor John C. Cooper, legal adviser to the International Air Transport Association.**

LESS than half a century ago the world was startled by the announcement that an aeroplane, piloted by the Frenchman Louis Blériot, had crossed the Channel, thereby penetrating the airspace of the United Kingdom. Today, air transportation is a commonplace method of travel.

With the extension of conventional rocket programmes by the launching of satellites into orbits the matter has been carried a stage further. Whether this generation will experience a new form of locomotion known as space travel remains to be seen. From all accounts it does not appear to be impossible.

In any event, developments designed to explore interplanetary space have already gone far beyond the realms of science fiction. This raises practical legal questions not yet covered by existing rules of international law. The three most important are the altitude of territorial airspace sovereignty, the rules of navigation relating to space vehicles, and the law of discovery of planetary bodies.

**Territorial Airspace Sovereignty.** Two schools of thought concerning territorial airspace sovereignty were developed in the latter part of the nineteenth century. Both agreed that no customary international law governed locomotion in the atmosphere above the Earth's surface. On all other issues they were divided.

The one maintained that the atmosphere surrounded the Earth, and that all political entities bordered the atmosphere in the same way that maritime territories bordered the sea. Therefore, the same rules applied to the air as applied to the sea. Since the freedom of the high seas had been established in international law, freedom of the atmosphere was a logical consequence. Thus, as no nation could exercise jurisdiction over the high seas, no nation could exercise jurisdiction over the atmosphere. Therefore, the right to penetrate the atmosphere above a political entity should be unhampered.

The other approach was much simpler. It maintained that since States exercised absolute sovereignty over and beneath the surface of their territories, they were entitled to exercise similar jurisdiction above the atmosphere of their territories.

The matter was resolved in international law by the 1919 Paris Convention on Air Navigation. Article 1 provided that contracting parties recognized that every Power had complete and exclusive sovereignty over the airspace above its territory.

Though the United States did not ratify the Paris Convention, it asserted its sovereignty over the airspace above its territory through the medium of its Air Commerce Act, 1926. This assertion was followed consistently in the Havana Pan-American Convention, 1928, and the U.S. Civil Aeronautics Act, 1938. It came as no surprise, therefore, that at the Chicago Conference, 1944, not only did the United States agree to, but it actually sponsored, the inclusion of this firmly established principle of international law in the Chicago Convention, 1944.

Most States are contracting parties to the Chicago Convention into which the principles of the Paris Convention, 1919, have flown. The Chicago Convention, which replaces the Paris Convention, provides in Articles 1 and 2 that contracting States recognize that *every* State has complete and exclusive sovereignty over the airspace above its territory. The territory of a State is deemed to be the land areas and territorial waters adjacent thereto, under the sovereignty, suzerainty, protection or mandate of such State. The territorial airspace sovereignty of non-contracting States as well as contracting States is recognized.

The Soviet Union did not adhere to the Paris Convention, 1919. Nor has it done so in respect of the Chicago Convention, 1944. Nevertheless, the Soviet Air Code of 1932 makes it quite plain that the U.S.S.R. subscribes to the universal principle in international law concerning territorial airspace sovereignty. This is confirmed in the Soviet Air Code 1935.

No attempt has been made to define the meaning of airspace, either in the Paris Convention, 1919, or in the Chicago Convention, 1944. Examination of the background leading up to the Paris Convention, 1919, clearly indicates that the main concern of contracting parties was strategic. After the events of the First World War, no State was disposed to allow a foreign object to proceed over its territory at any height or speed, unless prior authorization from the sovereign Power concerned had been obtained. It is true that the Paris Convention describes the vehicles used for flight as "aircraft," which was defined as covering all machines capable of remaining airborne with the aid of the resistance of the air. However, at that time, it was not envisaged that any other type of vehicle would be used for transportation above the Earth's surface. Nevertheless, even then, and in spite of the use of the term "airspace" in the English text, the French version of the Paris Convention employed the phrase "*espace atmospherique*" which, literally translated into English, means "atmospheric space."

The Chicago Convention also defines "aircraft." However, by 1944 it was apparent, particularly in view of the German rocket programme as well as general development of jet propulsion, that "aircraft" had assumed a much broader meaning. In the French version of the Chicago Convention the broad English term "airspace" appears once again as "*espace atmospherique*." The French language is one of the official languages of the International Civil Aviation Organization.

According to an official Soviet manual on international law, "air" is defined as "the column of air above the territory of the U.S.S.R. including land and water, comprising the troposphere and the stratosphere. This manual asserts that there are no laws permitting limitation of the air under national jurisdiction. Furthermore, that these regions of the air are undergoing continual extension in proportion to the increases in the ceiling of aircraft."

Many writers have attempted to define "airspace." Professor John Cobb Cooper has suggested that both the Paris and Chicago Conventions deal with objects which derive their support in the atmosphere from reactions in the air (such as balloons and aeroplanes) and not with rockets, satellites and other such spacecraft designed to move through space without atmospheric support. According to this theory a rocket propelled in the atmosphere only a few miles above a State's territory would not infringe the territorial airspace sovereignty of that State.

Other writers have distinguished between air and atmosphere and have argued that airspace has a specific meaning.

Paying due regard to all developments, this writer considers the situation to be the following. In interpreting relevant articles of the Chicago Convention, one must bear in mind certain canons of construction laid down in 1952 by the International Court of Justice. Thus, it is not possible to base the construction on a purely grammatical interpretation of the text. One must seek an interpretation which is in harmony with a natural and reasonable way of reading the text, having due regard to the intention of the parties at the time they bound themselves by the Convention. It would require special and clearly established reasons to do otherwise.

That being so, it must be conceded that the term airspace has a very broad meaning. Furthermore, the translation of the equivalent French expression in the text is "atmospheric space." Nothing is gained by casuistic arguments as to the exact meaning of "air."

To the lay mind the simplest definition of an atmosphere, which has the advantage of being common ground among most scientists, is that it is an envelope of gas, if any, which surrounds a body in space. It follows that the Earth's atmosphere is the envelope of gas that surrounds the Earth.

Thus, airspace or atmospheric space, as used in the Chicago Convention, 1944, may be defined as that space enclosed by the projection of the radii of the earth passing through and above surface political boundaries, until such radii reach the notional frontier dividing the Earth's atmospheric envelope from the sparse interplanetary gas which is reputed to permeate interplanetary space.

It may be argued that the notional frontier between the Earth's atmosphere and interplanetary space would be at too high an altitude to be the practical limit of a nation's territorial airspace sovereignty. That may be so. Nevertheless, pending agreement to the contrary, that notional frontier is the logical consequence of the intent of the parties who drafted Articles 1 and 2 of the Paris Convention, 1919, the broad general terms of which were incorporated into Articles 1 and 2 of the Chicago Convention, 1944. The alternative is an altitude of just under 20 miles above the Earth's surface.

It may be presumed that, with the launching of Sputnik 1 as a Soviet national experiment, the U.S.S.R. does not consider

## THE LAW OF SPACE . . .

that territorial airspace sovereignty extends beyond an altitude of about 560 miles. Otherwise she would be violating the sovereignty of other States over which Sputnik I can be seen.

**Rules of Navigation in Space.** Once agreement has been reached on the altitude of territorial airspace sovereignty it will be necessary to define the regions beyond it. This will require legal meanings to be given to such expressions as airspace, atmosphere, space, interplanetary space and interstellar space. At present, these are often used interchangeably.

An important question that will have to be decided is the legal status of space beyond the agreed altitude of territorial airspace sovereignty. In discussing this matter some writers have drawn analogies from international rules pertaining to the high seas. But analogy is a dangerous snare.

The basic precedent that the Paris and subsequent Chicago Convention have established is that the origin of all international law affecting the area above the Earth's surface is not derived from principles and precedents built up throughout the ages.

These Conventions are law-making treaties which are a source of international law of great importance. They stipulate new general rules for future international conduct. Where appropriate, they confirm, define or abolish existing customary or conventional rules of a general character.

Consequently, the fact that freedom of the high seas is a customary rule of international law has no bearing on what should be the law concerning navigation in the space above and beyond the altitude of territorial airspace sovereignty. Any rules concerning such navigation must be formulated, in accordance with the established precedent, by international agreement.

This raises the question of the von Braun space station. In order to obtain the enormous public funds required for this project it has been justified as an invulnerable bombing platform that will enable the United States to maintain world peace. At a height of 1,075 miles, it is proposed to circle the Earth once every two hours. By means of special optical instruments United States personnel would be able to observe an attack by any nation before it could get properly under way. Atomic missiles would then be launched from the space station on to relevant Earth targets. The war would thus be ended before it started.

Soviet scientists are reported to be working on similar projects. Unlike those of the United States, and probably because they can get all the money they need, Soviet scientists do not announce the object of the exercise.

Assuming all this to be possible, and leaving out the question as to what effect a rocket with an atomic warhead launched from Earth might have on these space stations, the first question that arises is whether the all-seeing eye of the space station would not be violating territorial airspace sovereignty. Would any State, in the absence of previous agreement, based on reciprocity, be prepared to allow another State to penetrate its national territorial airspace sovereignty to that extent?

Obviously, the idea in itself could go a long way towards maintaining international peace, always assuming that such a space station can be built, provided that this station is manned by an international staff under the terms of an appropriate international agreement.

At this stage, however, it might be as well to remember that the basic goals of the satellite project are meteorological and geophysical observations of the earth, and astronomical studies. It would, therefore, be advisable to come to some arrangement whereby, on the basis of reciprocity, an international inspectorate has the opportunity of examining the contents of these state-owned space vehicles before they are launched into an orbit. Similarly, States would probably allow Earth satellites to navigate peacefully in their orbits, provided there were an effective system of dissemination of the scientific information obtained. Care will also have to be taken to ensure that the provisions of the International Telecommunications Conventions with regard to the use of authorized frequencies are not breached.

Provided the matter is given enough thought, it will probably be found at this stage that the projection into space of the existing international system of air navigation, appropriately amended, could be achieved without very great political difficulty. Thus these vehicles would acquire a nationality by registration with the launching state. The flag state would, thereby, assume responsibility to ensure that the vehicle complied with all rules and regulations in force and would be responsible for any damage incurred.

**Discovery of Planetary Bodies.** As regards the law relating to "discovery" of planetary bodies, the position could be a little more complicated.

If the United States succeeds in its announced project of launching a manned spaceship to the Moon—or, alternatively, if the Soviet Union succeeds in discharging a mobile laboratory on to that satellite—will this mean that new territory has been discovered? That is to say, will it serve as evidence, symbolic or otherwise, of possession? Will it ultimately lead to claims of sovereignty?

If principles and precedents to answer these questions are sought from the international law that prevailed four centuries ago the answer might be in the affirmative. But international law is a living organism which has passed through many evolutionary stages.

Claims of sovereignty acquired by discovery are still governed by the international law that prevailed at the time the claim was created. However, during the period under review, the law of discovery has altered considerably. Therefore, at any given time, relevant legal systems prevailing at successive periods may be applied to each case.

The system of law applicable to the area above the Earth's surface was created and developed for that specific purpose in the twentieth century through the medium of law-making treaties. The system is self-contained, and principles and precedents from other branches of international law do not apply. The major precedent established by the system is that any development of law in the atmosphere or beyond must be by international agreement.

# Problems of Satellite Flight

THE legal problems raised by satellite flight were discussed in London on Wednesday, November 27, in a talk by Professor John Cobb Cooper, legal adviser to the International Air Transport Association and formerly Head of the Institute of International Air Law, McGill University. He was addressing members of the British Branch of the International Law Association. The lecturer's main conclusions were that there were three regions into which airspace and space could be divided; and that the international law affecting these regions should accordingly be based on three distinct methods of approach.

We had arrived at an entirely new era in transport, Prof. Cooper began, and the basic factors in connection with any form of transport were concerned with the medium through which the vehicle moved, the vehicle itself, and its contents. The three main problems at present were: 1, What was the legal status of the areas of space through which a satellite moved; 2, What was the legal status of a satellite itself; and 3, What questions of international control must be answered? These were the current problems of air law, as it used to be called, or flight-space law, as the speaker preferred to describe it.

Reviewing the historical background, Prof. Cooper first pointed to the 1909-1919 period during which, he said, it had become gradually but firmly accepted by States that a country's sovereignty extended to the airspace above it. The airspace above the high seas, logically, was not the subject of control by any one country. As a guiding rule the international legal historian should be concerned with the acts of States rather than judicial decisions, and in this respect it was clear that the principle of three-dimensional territorial rights had been assumed by all countries concerned. The declaration of war by Germany in 1914, indeed, had quoted infringements of German and Belgian airspace by French aircraft. In the Paris Convention of 1919, therefore, States did no more than to state existing international law.

There had been little extension of the implications of this philosophy prior to the new period of today, when we were engaged in determining whether or not there was an upper limit to national control of airspace. Sovereignty of airspace was now being limited, not created.

Referring to the lack of a satisfactory definition of the word airspace, the speaker suggested the use of the term "flight-space" to cover all regions of air and space in which flight might take place. "Airspace" as used in the Paris Convention, and later adopted in the Chicago Convention, was intended to mean—and should still be considered to mean—those regions where the gaseous atmosphere was sufficiently dense to support the flight of balloons and aircraft. National sovereignty should apply in this region but, above it, while nothing precluded the enforcement of national sovereignty, there was no basis on which current international air law could be applied. On the incidental question of whether outer space could be seized and held by a controlling Power, Professor Cooper's personal opinion—and fear—was that it could.

Recent developments in rocket-powered flight, he continued, had defeated the old restrictions on heights attainable which had applied when Conventions relating to airspace had been drafted. The forthcoming X-15, intended to permit human aircraft flight up to 100 miles high, was in effect both an aircraft and a spaceship. Such developments, in the speaker's opinion, did not mean that the limit of national airspace should automatically be raised.

As regards outer space, there was more than mere doctrine to indicate that national sovereignty did not extend there. In the publicly announced plans for both Russian and U.S. satellites, permission for the satellites to pass over other countries at a height of several hundred miles had not been requested. No country, furthermore, had objected. Proposals had been made in various quarters for an international agreement to ensure that space flights should be made for peaceful purposes only. The entire course of international conduct indicated that outer space was not the property of any one state; from a legal point of view it was similar to the high seas.

The fact remained that the two satellites now in orbit passed only 125 miles from the Earth at their closest points—much nearer than had previously been thought possible. And they were being slowed down by the atmospheric drag in that region. While the air density was here not sufficient to *support* flight, it was sufficient to *affect* flight.

This led the speaker to put forward his own conclusions in the form of three proposals. Firstly, history would demonstrate that airspace, and national sovereignty, extended to the height at which the density of the gaseous atmosphere failed to support flight. Secondly, it seemed clear that outer space was beyond the sovereignty of any State. Thirdly, an international decision must be made concerning the intermediate region, which might perhaps extend from 50 to 500 miles high. It would be wise to agree internationally on this last point since, without an international decision, the term "airspace" might be interpreted to include that portion of the gaseous atmosphere which affected, rather than supported, flight. A final incidental point was that, while satellite flight was not legally the same as the flight of an aircraft as now understood, it seemed to the speaker that the State which launched a satellite should certainly be responsible for its international good conduct.

During the brief discussion period which followed his talk, Prof. Cooper said that the principle of national sovereignty of airspace up to the limit at which control could be exercised could lead to serious difficulties. A small State might be capable of exercising control up to, say 20 miles while its neighbour, a more powerful State, might be effective up to 200 miles. It was an open question whether less nationalism and more freedom of airspace in the early days would or would not have improved the legal situation today.

# Stand-off Bombs

## Optimum Trajectories for Winged Supersonic Bombardment Weapons

By D. E. BAILEY, M.A., Ph.D.*

THE advent of the atomic bomb in 1945 heralded a new era in bombardment weapons, the use of the V.1 and V.2 having given an indication of the means by which these new weapons could ultimately be delivered. A nuclear warhead can be carried to its target in several ways. It can be fired from the ground in either a ballistic missile or a flying bomb, or can be carried in a bomb released from an aircraft. To release a conventional bomb, the aircraft must approach within a few miles of the target. With the sophistication of guided-missile defence systems such an approach will become very hazardous for the bomber, and for this reason the conventional bomb must be superseded by the stand-off flying bomb, released outside the perimeter of the defences.

Because of its high speed, the ballistic missile is difficult to intercept; but as a consequence of this speed it presents heating problems during its re-entry into the atmosphere. Guidance must be very accurate during the early stages of flight, because a ballistic missile cannot be controlled once it leaves the atmosphere. Such missiles are heavy and require special launching sites. A flying bomb, on the other hand, never leaves the atmosphere and can be guided throughout its flight in the same manner as an aeroplane. It does not need to be launched with great precision, and it can be despatched from a mobile launcher, or released from an aircraft. In order to reach its target, a flying bomb must fly sufficiently high and sufficiently fast to evade the defences.

The skip vehicle is a hybrid between a flying bomb and a ballistic missile. It has wings and can be controlled in the same way as a flying bomb, but a large part of its flight is spent outside the atmosphere in a series of ballistic skips. After launching, the missile climbs rapidly and leaves the atmosphere on a ballistic path. On re-entry, lift is applied and the vehicle pulls up into a second ballistic skip. This oscillatory motion is continued throughout the flight, and is illustrated in Fig. 1, in comparison with the trajectories of a ballistic missile and a flying bomb. The skip trajectory is only efficient for a long-range missile travelling at high speed. Because of its heavy weight and large wing-area, a vehicle flying such a path cannot be carried by an aircraft and is suitable only for ground-launching.

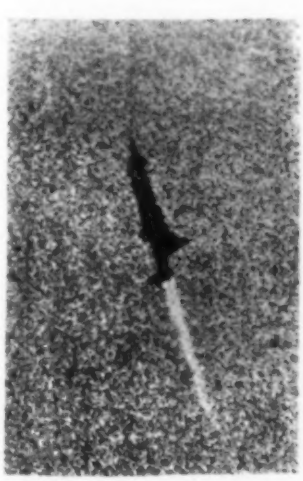
It will be seen from Fig. 1 that, after acceleration and climb to altitude, the major part of a flying bomb's trajectory is nearly horizontal. It is the purpose of this article to consider different types of these trajectories and to discuss the flight-path optimization problems involved.

Of all the design parameters which have to be determined the type of powerplant has the most marked effect upon the shape of the trajectory. The cruise motor can be a rocket, turbojet or ramjet. For air-launched missiles the cruise motor can be supplemented by a boost rocket which may be retained or may be jettisoned after its fuel is exhausted. Ground-launched missiles have, in general, jettisonable rocket boosters. Once the type of powerplant and general aerodynamic configuration have been determined, the optimization problem reduces to a detailed consideration of powerplant size, wing area, fuel volume, structure weight, maximum speed and flight-path. Most of these parameters are interrelated, and optimization is equivalent to finding the best compromise between them. For each configuration an optimum flight-path can be found (the expression "flight-path" is used to include the variation of both altitude and speed). It has already been stated that the major factor affecting the flight-path is the type of powerplant. In the following paragraphs optimum shapes of flight-path for different powerplants are considered.

Before discussing the trajectories in detail it is necessary to consider the differences between the propulsion systems, comprising solid-fuelled and liquid-fuelled rockets and turbojets and ramjets. Rockets yield a maximum thrust which is nearly independent of speed and altitude. Solid rockets give a fixed thrust, but the thrust of liquid rockets can be controlled. At the same thrust, liquid rockets have a better specific fuel-consumption than solid rockets, but a greater structure weight. The maximum thrust of turbojets and ramjets at a given speed in the stratosphere is nearly proportional to kinetic pressure. The variation of thrust (T) divided by kinetic pressure (p) is shown in Fig. 2 for a typical turbojet with reheat and a typical ramjet of the same diameter. Below the tropopause these values of T/p are reduced. A ramjet is a lighter engine than a turbojet of the same diameter. The specific fuel consumption of a rocket is many times that of a turbojet or ramjet. If a ramjet is controlled to a thrust below its maximum, the reduced fuel-air ratio leads to a lower specific fuel-consumption.

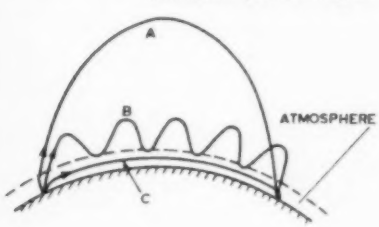
Trajectories of rocket-powered flying bombs are of two broad types: boost-glide and boost-cruise. In both cases, and whether ground-launched or air-launched, the missile is boosted transonically, and then climbs fairly steeply. In the boost-glide case maximum thrust is maintained until the fuel is exhausted at a high Mach number, and the missile glides without power for the remainder of its flight. It accelerates and glides with maximum L/D (lift-drag ratio), climbing during the acceleration and descending during the glide. On reaching the target it turns over into a steep dive. A trajectory for a ground-launched rocket-propelled boost-glide missile is shown in Fig. 3. In the boost-cruise trajectory, on the other hand, maximum thrust is maintained until the missile reaches its predetermined maximum cruising speed. Thereafter the missile cruises in a nearly horizontal path at the maximum L/D, climbing slowly as fuel is used. A trajectory for an air-launched boost-cruise missile is illustrated in Fig. 4. In general, greater range is achieved for the same configuration by flying a boost-glide rather than a boost-cruise trajectory, but the heating problem at the higher speeds of the former necessitates the carriage of additional equipment and an increase in structure weight. For

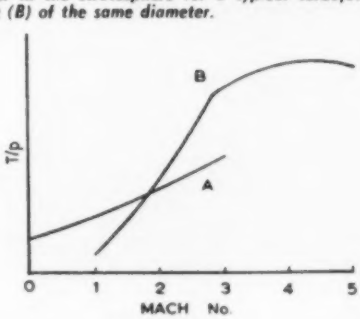
*Launch of a GAM-63 Rascal air-to-surface weapon (described on p. 894) from a B-50, during development trials at Holloman A.F.B.*



*This photograph, taken through a telephoto lens near Patrick A.F.B., Florida, shows the vertical launching of the big Navaho supersonic ramjet-propelled, long-range missile. Navaho is described on page 901.*

*Fig. 1. Trajectories for ballistic missile (A), skip vehicle (B) and flying bomb (C). Fig. 2 (right). Variation of thrust/kinetic pressure with Mach number in the stratosphere for a typical turbojet with reheat (A) and a typical ramjet (B) of the same diameter.*




*Head of Assessment Section, Weapons Research, A. V. Roe and Co., Ltd.*

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*Fig. 3 (left). Trajectory for a ground-launched rocket-propelled boost-glide missile. Fuel is exhausted at the point marked (A). Fig. 4 (centre). Trajectory for an air-launched rocket-propelled boost-cruise missile. Fig. 5 (right). Climbs for air-launched turbojet (A) and ramjet (B) missiles.*

## STAND-OFF BOMBS . . .

rocket-powered missiles detailed optimization of the climb leads to achievement of maximum range.

Air-breathing engines have an upper limit of speed at which they can be used. A Mach number of approximately 3 is the ultimate limit for turbojets, and a Mach number of about 5 for ramjets. It is, therefore, clear that trajectories for missiles with air-breathing engines must be of the boost-cruise type. The cruise is flown at the maximum L/D, and, because of the variation of thrust with altitude, engine size and wing area must be matched to the required performance. In the case of the ramjet it is desirable to fit larger engines and to cruise with reduced thrust. The effect of the extra engine weight is more than compensated by the reduction in specific fuel-consumption so obtained. The optimum cruise is, therefore, flown at maximum L/D ÷ s.f.c.

Ground-launched turbojet and ramjet missiles must be boosted transonically to a speed at which their own engines can take over. They then accelerate in a gentle climb until the cruising altitude is reached.

For air-launched turbojet and ramjet missiles all-up weight is very important, because of the limitations of the carrying aircraft. In order to retain as much missile fuel as possible for the cruise, it is desirable to reduce the size of the rocket boost to a minimum, particularly if the booster is not jettisoned. A turbojet missile can be flown without a rocket, but in the ramjet missile a rocket boost is essential, since the ramjet will not give thrust until the missile is flying supersonically. Normally, after a period of initial acceleration, the missile powered by an air-breathing engine accelerates in a gentle climb until its cruise altitude is reached. Speed and altitude must be matched during this climb to keep the engine internal pressure to a minimum, thus permitting the use of a lightweight engine. For a turbojet missile the initial period of acceleration can take place in nearly horizontal flight, but for a ramjet missile it is desirable to accelerate in a dive; potential energy is changed into kinetic energy and the speed at which the ramjet can take over is thus achieved as soon as possible. The ramjet fuel used in climbing to regain altitude is small compared with the rocket fuel saved by this manœuvre. Climbs for turbojet and ramjet missiles are compared in Fig. 5.

It is clear from the foregoing that the choice of powerplant for a flying bomb depends upon the range and speed that is required. The general shape of trajectory can then be determined, but detailed optimization is very important.

## ROCKETS FOR RESEARCH (continued from page 888)

(4) To determine the undisturbed ambient pressure at various altitudes: three Pirani pressure gauges carried in the rocket cone, one measuring ram pressures at the tip, and the other two measuring cone wall pressures. (An R.A.E. investigation.)

**France and Japan.** French work on sounding rockets has included the massive Veronique, a development of the German V-2 with a payload of 130 lb. This rocket has attained an altitude of 84 miles, and incorporates 20-channel telemetry. Work on Veronique, which has recently been displayed with modified fin surfaces, is taking place at the Colomb Bechar research centre.

In Japan, the I.G.Y. programme includes two sounding-rocket projects designated Kappa and Sigma. The former involves a multi-stage, solid-propellant rocket designed to carry a 15 lb payload to 80 miles; and the latter is a rockoon system with a small rocket (total weight about 25 lb) having a peak altitude of 55-65 miles. Twenty Kappa rockets are being fired from the Akita test centre of Tokyo University in northern Japan, and will measure air pressure, solar radiation, ion density, cosmic rays, temperatures and winds.

**The Soviet Union.** Russian efforts in the field of high-altitude research have already produced the world's first two artificial satellites. This tremendous achievement, and the new knowledge it provides, must be at once the most important and the most interesting facet of Russian research; it is supported, nevertheless, by a large-scale programme of sounding-rocket measurements. Referring to Soviet I.GY. participation, a Moscow scientist said recently that over 100 research rockets were to be launched to 50-125 miles from three sites.

The first sputnik launched on October 4, is a 23-inch sphere weighing 184 lb. It carries two radio transmitters (20.005 and 40.002 Mc/s) which continued to operate for three weeks, and which were stated by *Pravda* to have transmitted (by variations in frequency and timing) measurements such as temperatures.

Concerning the experimental data which artificial satellites in general would provide, *Pravda* noted these points:

"As regards cosmic rays, the programme provides for the study of the relative content of various nuclei in primary cosmic radiation. In particular, scientists are to determine the relative content of the nuclei of lithium, beryllium and boron, and also high-charge nuclei. . . .

"The Sun's short-wave radiation has not so far been studied because of its absorption by the atmosphere. The satellite, revolving at a great height, will make it possible to study the ultra-violet and X-ray sectors of the solar spectrum and to determine the variations in the intensity of solar radiation. This will be most important, for it is now believed that it is the Sun's short-wave radiation that causes the ionisation of the upper layers of the atmosphere. Since the Sun's short-wave radiation is caused by the corona, the data received will provide new information about the structure of the corona.

"In addition to the Sun's short-wave radiation, the processes in the upper layers of the atmosphere are greatly influenced by the Sun's corpuscular radiation. Because of this, it is most important to establish the nature of the corpuscular radiation, its intensity and the power spectrum of the particles shot out by the Sun and to establish the role of the Sun's corpuscular radiation in the auroral displays. . . .

"Of considerable interest will be the study of electrostatic fields at great heights (in the region of 600 miles). The satellite will also help to establish whether the Earth with its atmosphere forms a charged or a neutral system. . . ."

The second sputnik, launched on November 3, was stated to be carrying a payload (including dog) of 1,120 lb and to have an initial apogee (furthest distance from the Earth during orbit) of about 1,055 miles. Its radio and telemetry equipment ceased to function after one week. A published diagram showed this satellite not to be spherical, but to consist of the last stage of a rocket. The diagram, together with additional technical details of the satellite, was printed in *Flight* of November 22.

Certainly the most generally interesting, and possibly the most significant, aspect of the second satellite, was the fact that it carried a living animal inside it. In the dog's hermetically sealed chamber was measuring equipment to record the animal's physiological functions and also equipment for air regeneration and feeding. The pulse-beat and breathing of the dog, together with its arterial blood-pressure and cardial biopotentials and the temperature and pressure in the chamber, were recorded and telemetered to the ground stations.

In order to regenerate the air inside the chamber and maintain the required gas composition, highly active chemical compounds were employed, giving off the necessary amount of oxygen for inhalation, and absorbing carbon dioxide and the surplus vapour. Owing to the absence of air convection in conditions of zero gravity, an arrangement for forced ventilation was installed.

Although short-duration flights up to 120 miles had previously been made by animals in upper-air rockets launched from the U.S.A., the dog Laika's journey in Sputnik II was the first in which it was possible to study the protracted effects of zero gravity on a living organism.

An intriguing postscript to the Sputnik II reports was given in Moscow on November 21 by Professor Vitaly Ginzburg, who said that observation of satellite orbits might provide verification for certain parts of Einstein's general theory of relativity. Particular effects in this theory which could be checked included the lag in cosmic time behind Earth time.

This is the effect which is claimed to produce the anomalous behaviour often referred to in science-fiction stories and described by Ginzburg as follows:

"The difference in the time readings on the Earth and on the satellite will be very small, amounting to no more than some hundredths of a second per year. Considering the universe with its cosmic speeds as a whole, however, the effect will add up to many months and even years. The passengers of some future photon rocket leaving the Earth on a space trip of several years—according to their scale of things—will return to Earth in a matter of dozens of terrestial years. Such a trip is largely in the realm of fantasy, but is perfectly feasible in principle."

It is in these directions—tomorrow's directions—that today's rockets for research are pointing.

K. T. O.

# ARMSTRONG SIDDELEY

Flight, 6 December 1957

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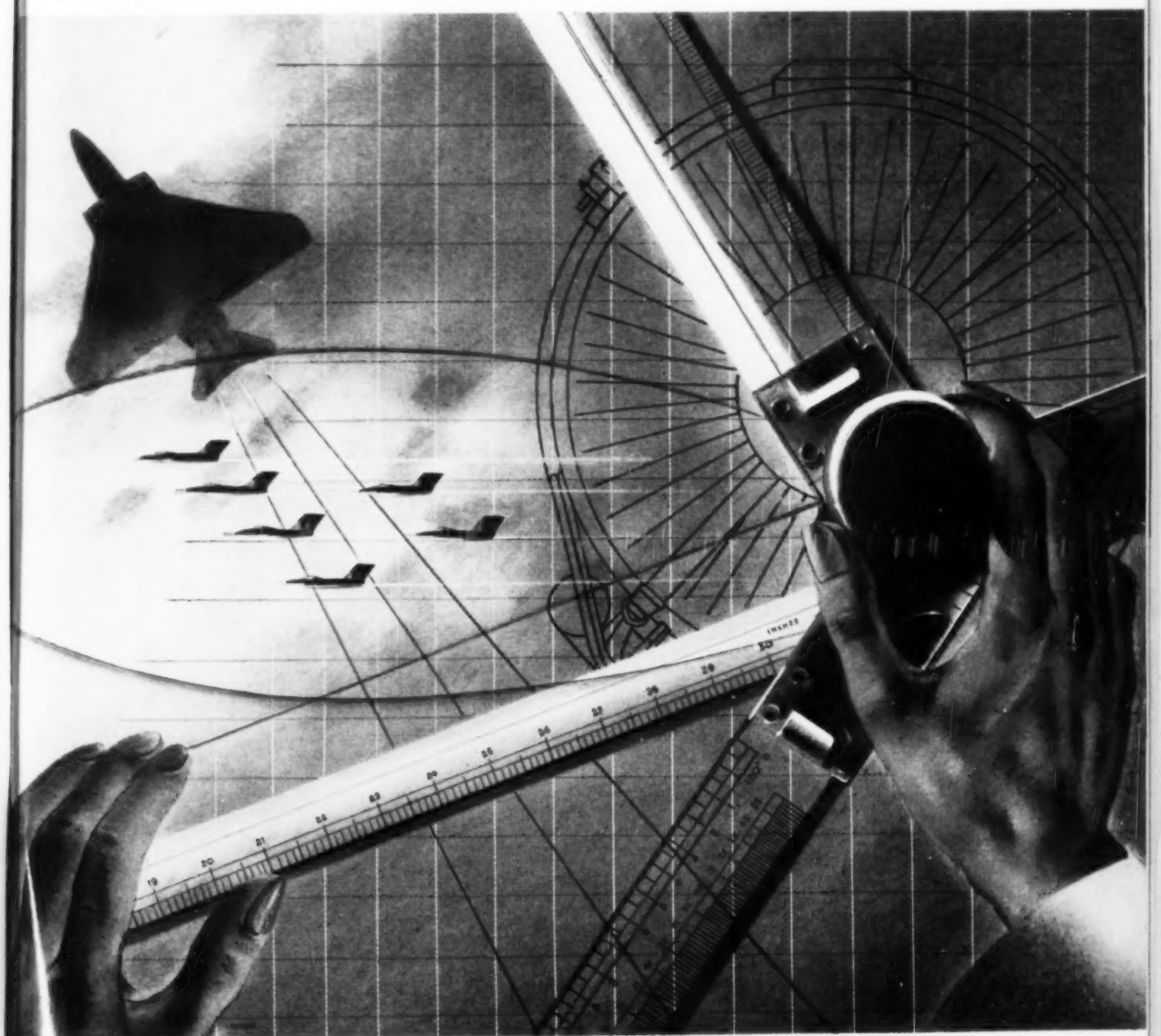

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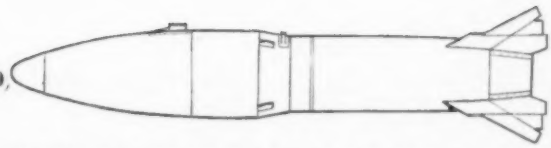
# MISSILES 1957 . . . (continued from p. 880)



**Douglas MB-1 Genie** Air-to-air. Solid sustainer motor. Length, estimated at 9ft; diameter, about 17in over the warhead; firing weight, probably about 1,000 lb.

## U.S.A.

### *AIR-TO-AIR*

**B.D.M.** In our 1956 review we published notes on the various bomber-defence missile systems then current. No weapon system has been so hesitantly played with in recent years, but the two examples quoted below are still active programmes.

*WS-126A* It is intended that this system should replace the gun turret at present carried by the B-52. Engineering manager is Cornell Aeronautical Laboratory and among the companies involved are Bell Telephone Laboratories, Hughes Aircraft and Raytheon. The last-named examined the unique problems of cross-wind and rearwards launching with test vehicles fired one year ago from sleds at Holloman. Cornell's data has been turned over to industry and, although still bearing high priority, the system is in partial abeyance.

*WS-132A* This is the B.D.M. for the WS-110A chemical-fuel supersonic-cruise bomber (for which either Boeing or North American will receive a contract in a matter of weeks). There were two systems involved, one by G.E. and McDonnell and the other by Westinghouse and Republic, but both are reported to have been terminated late last year. Presumably the programme will be re-activated when the configuration and performance of the aircraft are known with certainty.

**Diamondback** It is known that the Sidewinder family of heat-homing air-to-air missiles is being progressively improved and is leading to more sophisticated weapons. Diamondback (likewise a member of the rattlesnake family) is reported to be the designation of one of these weapons.

**Duck** Originally reported in 1956 to be part of the weapon system of the Convair B-58 (WS-102A/L), Duck is stated to be an air-to-air weapon of the U.S. Air Force intended for the armament of "long-range supersonic bombers." Fairchild is reported to be the prime contractor and the system is said to have been in the research and development stage in July of this year. It is related to the Goose missile referred to on page 899.

**Falcon** One of the first air-to-air weapons to go into service anywhere in the world, Falcon is small enough to be carried and fired in salvo by U.S.A.F. intercepters. Development of the system as it is known today began under the management of Hughes Aircraft in 1950; the history was related in our 1956 review.

At the Hughes plant at Tucson, Arizona, there are now two types of Falcon in production: the GAR-1 series with radar guidance and the GAR-2 series of infra-red heat-homers. Many thousands of examples of the former family are in service with the U.S.A.F. Air Defense Command, current production being centred on the GAR-1D. The cylindrical body, for which Solar Aircraft at Des Moines is a major sub-contractor, is built up from magnesium castings. It houses beneath a bonded radome a semi-active radar which receives coded pulses from the intercepter reflected by the target. The warhead is relatively small, and at the rear is the Thiokol M58-E4 solid sustainer motor. Around the nose are four stabilizing fins and at the rear is a cruciform of wings; the latter are built up from a magnesium frame with a glass-fibre laminate skin, cured to give an inward buckle over unsupported portions so that differential expansion due to aerodynamic heating gives better stress distribution. At the rear are the control surfaces which, in the 1D and later versions, are carried well aft of the wings.

Production GAR-1Ds cost about $19,000 when they entered production last year, and about $12,000 today. Compared with their predecessors they have better performance and manoeuvring power at high altitude. The weapon is carried by all the A.D.C. aircraft, and by the F-101B which has a triple installation on a rotary door.

Similar in external configuration to the GAR-1D, the infra-red GAR-2A was planned in 1952; it is in production at Tucson at a cost of rather more than $9,000. Like most infra-red weapons, the seeker head is slaved to the target before the round is fired, and the homing accuracy is reported to be fractionally better than that demonstrated by the radar Falcons. A surprisingly large contract is the $2.25m awarded last month to the Hamilton Watch Company for "aircraft data recorders" in the development of the GAR-2 system. The infra-red Falcon has behaved extremely well when fired by F-102As against TM-61A, QF-80 and other aircraft and air-launched rockets. Mixed with radar GAR-1Ds it should be possible to achieve a kill-probability approaching 90 per cent with good resistance to countermeasures. Compared with the GAR-8 (Sidewinder), GAR-2 is a more sophisticated, all-weather system.

**Genie** Several years ago Douglas studied the concept of an air-to-air weapon with a nuclear warhead, and this was re-activated in 1955 to produce a weapon which would be lethal to attacking aircraft over a very wide radius. Originally the device was called Ding Dong, and later High Card, but its present soubriquet is that given above, and the designation is MB-1.

Douglas remain managers for the complete system, which includes substantial pylons on the carrying aircraft. As the drawing shows, the missile has no wings, and guidance takes the form of gravity-correction and rudimentary steering effected by the four movable fin-tips. Propulsion was to have been effected by an N.A.A. Rocketdyne liquid-propellant motor, but the sustainer is now a solid charge by Aerojet-General which burns for the first 9,000ft of flight. At the front is the warhead, developed at the Los Alamos laboratory of the A.E.C., with a yield of about 1.5 kilotons.

In 1955 a similar warhead was ballistically dropped at Holloman, and the complete weapon system has been one of the major responsibilities of the 4950th Test Group (Nuclear) of the A.R.D.C. since that time. Numerous rounds have been fired with conventional warheads, and Ting-a-ling is given as the name of a training version with a spotting charge. First aircraft capable of using the MB-1 system is the Northrop F-89J, and most of the earlier F-89s are being converted to this standard. Hughes received a $380,139 contract last month for the MG-12 fire-control system (a development of the E-9 used in the F-89H), which both fires the weapon and detonates its warhead. The flexibility of the MB-1 system permits attack from any direction, rendering collision-course fire-control inappropriate. A round was fired at 18,000ft from an F-89J last summer at Yucca Flat, Nevada, the aircraft pulling 3g to escape as soon as the missile left. The weapon travelled about 6,000 yards horizontally and was detonated by ground command; numerous observers were unprotected at ground-zero but suffered no ill effects.

Very large scale production is expected to be undertaken at Santa Monica for the U.S.A.F. Air Defense Command. Principal future carriers of MB-1 will be the Convair intercepters; the F-102 can be equipped to carry it on its underwing-tank pylons and the F-106 was designed to carry the weapon internally as its primary armament. In addition to procurement of the MB-1 for current use, the Air Force has asked for $19.1m to buy "mobilization reserve stocks."

**Sidewinder** Owing to its simplicity and to the large number manufactured, this is undoubtedly the cheapest homing missile in the world, yet it is an effective weapon for high-performance day-fighter aircraft. As we described in our 1956 review, Sidewinder was developed between 1948 and 1952 by the N.O.T.S. at China Lake, Cal., and has for three years been produced to BuOrd contract by the Philco Corporation. (General Electric have been second-source manufacturers for almost two years).

Beneath the hemispherical glass nose is a PbS infra-red seeker which, with its mirror system, occupies an axial distance of 4in. Behind is the guidance equipment, for which the Avion Division of A.C.F. Industries are subcontractors, followed by the servos which operate the canard controls which are stabilized by a tiny turbine running at very high r.p.m. The warhead has a total of 5 lb of high explosive with Honeywell fuzing, there being an influence fuze lethal up to 35ft-radius supplemented by contact fuzes at the tips of the control surfaces. The rear 75in of body houses the solid sustainer motor by Norris-Thermador, Hercules Power Company or Hunter Douglas. The charge is composed of propellant grains which are rolled into a sheet used to form a cylinder, which in turn is extruded to give a compact motor, the nozzle being 7in long and having an inside diameter of 3in. Burning time is two seconds.

Like most infra-red air-to-air weapons, Sidewinder's seeker operates from the moment its parent aircraft takes off. When the pilot hears the seeker in his earphones he triggers a switch which fires the solid-propellant gas generator which drives the accessory turbine, making power available for the guidance and control systems. The generator also provides current for the igniting squib of the sustainer motor. In spite of its exceptionally low diameter/length ratio, the missile can manoeuvre at from 10 to 14 g. Training missiles have a special exercise head, which explodes in a white flash for a miss or a red flash for a hit. Approximately seven out of ten Sidewinders fired during development and training have hit their targets, and several drones have been destroyed by the impact of unfuzed Sidewinders.

Several thousand rounds have now been delivered by Philco, against a number of contracts. For FY57 the Navy told Congress that each round cost "about $3,600," but it has been questioned whether this includes the whole expenditure. Appropriation for FY58 amounts to $38m and the missile is widely used throughout all carrier-based day-fighter squadrons.

*GAR-8* This is the U.S.A.F. designation of Sidewinder, for which quantity inventory procurement was made under FY58; G.E. were awarded a $17m production contract in October 1956. The GAR-8 incorporates a General Electric guidance unit and has been intensively engaged in air-firing since March. Principal carrier of GAR-8 is the F-104, which first fired the missile in May.

**Sparrow** The original Sparrow family was evolved for the Navy Bureau of Aeronautics as project Hot Shot by the Sperry Gyroscope Company. Test firings began in 1947 and the eventual Sparrow I, designated AAM-N-2, was evolved early in 1951. The weapon became operational in 1955 with both Atlantic and Pacific Fleets by which time ten years and four million engineering man-hours had gone into the system.

The basic missile has a pointed nose, a solid sustainer motor (by Aerojet-General, concentric grains with a plastic base) fixed tail fins and a moving wing cruciform. Guidance and control incorporates multi-axis gyros and accelerometers, aerials and receivers for detecting the intelligence in the fighter's radar beam, computing circuits to shape the signals to obtain proper beam-riding and servo-mechanisms for positioning the wings. The trajectory immediately after launching is controlled by inertial elements. Power supplies are furnished by electrical batteries and a high-pressure hydraulic accumulator, both close to the wing servos.

In June 1951 the Sperry-Farragut Division of Sperry-Rand was organized to build, equip and operate a Naval Industrial Reserve Aircraft Plant at Bristol, Tennessee. The 537,000 sq ft plant has produced thousands of Sparrow I missiles, conducting the manufacture, test and delivery of the whole system. No Sparrow prices have been published, but the breakdown of costing is as follows: avionics, guidance and control, 75 per cent; airframe, 12½ per cent; propulsion, 6½ per cent; warhead, 3½ per cent; remainder, 2½ per cent. Sparrow I went out of production one year ago.

*Sparrow II* This missile is described in the section dealing with the Dominion of Canada on page 876.

# Missiles 1957 . . .

## (*U.S.A.—continued*)

*Sparrow III* Although bearing the name of the Sparrow family and stemming from the earlier systems of that name, the new Sparrows are completely redesigned and far more effective weapons. Sparrow III incorporates, within the Douglas-developed airframe of Sparrow II, a new all-weather radar system, almost certainly of the fully-active type, which gives the new missile extremely good guidance through rain, clouds and other atmospheric phenomena.

System manager is the Raytheon Manufacturing Company of Waltham, Mass., who received a $60m contract for the Sparrow III system in October 1956. Early this year the company took over from Sperry the management of the N.I.R.A. plant at Bristol, Tennessee, and the weapon is now coming into full production and should become operational with the U.S. Navy next year. Sparrow III has a much bigger body than Sparrow I and also has larger aerodynamic surfaces for improved performance at altitude.

## AIR-TO-SURFACE

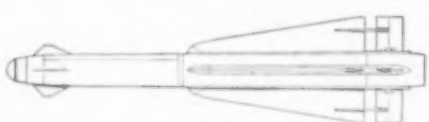
**Bulldog** Not yet referred to officially, this weapon is reported by the American Press to be an extension of Bullpup (*q.v.*). The range of Bulldog is given as 25,000 to 30,000ft and its burn-out speed about Mach 2.

**Bullpup** This neat air-to-surface weapon has been described as a 250-lb bomb with minimum propulsion, guidance and control. It was the winner in a Navy competition, entered by 14 companies, for a device capable of accurately hitting localized tactical targets without exposing the crews of manned tactical and carrier-based aircraft to intense defensive fire. Prime contractor is The Martin Company, who developed Bullpup from the initial brochure to completion of Phase A tests in under two years.

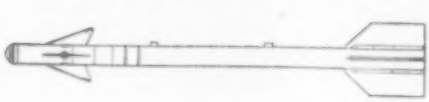
Propulsion is effected by a smokeless solid-propellant sustainer, reported to be produced by Aerojet-General. Above and below the motor nozzle are faired two tracking flares, and the missile is steered by command guidance—for which Republic Aviation is a sub-contractor—from the parent aircraft. Lift and control is provided by canard foreplanes and a cruciform of trapezoidal wings. Martin have emphasized that the inherent simplicity of Bullpup has held down system cost and facilitated rapid development. Production for the U.S. Navy and Marine Corps will shortly start at Orlando, and a variant is expected to be operated by the U.S.A.F.

**Corvus** Although a weapon system with this name was first reported in the winter of 1954-55, no official reference to it was made until the beginning of this year. In January the U.S. Navy Bureau of Aeronautics awarded Temco, of Dallas, Texas, a $16m study contract for a complete weapon system with this name.

The missile is a large, long-range, winged weapon stated to be under development for "a new Navy strike fighter"; presumably it would be carried by such aircraft as the A3J, F4H and F8U-2. Surprisingly, it is reported unofficially that Corvus is descended from the Fairchild Lark anti-aircraft weapon (which was of cruciform configuration and certainly did not have long range). It was stated last month that the decision to employ a solid sustainer motor for Corvus had "proved the death blow to U.S.A.F. interest" owing to the fact that it was considered impracticable to stretch the range to the figure required by the U.S.A.F. unless a liquid motor were fitted. Temco are handling most of the Corvus work at Garland, Texas, where 3,000 will be employed next month.



**Hughes Falcon GAR-2A** Air-to-air. Solid internal sustainer. Length, 77.8in; wing span, 20in; body diameter, 6.5in; firing weight, 122 lb (GAR-1D is 110 lb); burn-out speed, over Mach 2; operational range, about 5 miles.



**Philco/G.E. Sidewinder AAM-N-7** Air-to-air. Solid sustainer motor. Length, 9ft 5in; body diameter, 4.5in; fin span, approximately 19in; firing weight 155 lb; burn-out speed, Mach 2.5; range, 3,500 yd at sea level, rising to 6,000yd at altitude.

**Crossbow** As far as is known, this weapon system is the only operational contract held by Radioplane, a division of Northrop Aircraft (Radioplane were originally an associate company of Northrop holding corporate status). Bearing the U.S. Air Force designation GAM-67, the Crossbow prototype was reported to have been in the assembly stage in June last year, and during the summer of this year development prototypes were undergoing evaluation trials at Holloman A.F.B.

Little is known of the missile except for the fact that it is winged, air-launched and powered by a turbojet—probably a Westinghouse J81 (Rolls-Royce Soar)—at a level speed of approximately 500 knots. Bendix-Pacific have been supplying telemetering equipment for this system. In a recent House of Representatives discussion it was indicated that Crossbow had been "reoriented" (*sic*), and it seems that, owing to lack of money, the programme may not proceed beyond the development stage.

**Green Quail** This code name, reminiscent of those applied to British weapon systems, identifies the U.S. Air Force GAM-72 diversionary air-to-surface missile. Launched from a B-58 or equally important attacking aircraft, GAM-72 carries no warhead but is equipped with powerful countermeasures (presumably covering electronic, infra-red, sonic and all other possible systems) which should ensure immunization of its mother-aircraft against interception by defending aircraft or missiles. Apparently GAM-72 is non-recoverable, presumably being destroyed by remote command when its task is completed.

Prime contractor for GAM-72 is McDonnell Aircraft, of St. Louis, who in July received a research and development contract from the Air Materiel Command for $4,539,772. The missile itself is stated to be generically related to the Corvus family and to be guided by a Summers gyroscope (presumably it is constrained to remain in the general neighbourhood of its parent aircraft, although far enough away for the latter to be unharmed by a nuclear explosion). Green Quail is stated to be in the later stages of development and is expected to fly early in 1958.

**Petrel** Developed for the Navy BuOrd by the National Bureau of Standards and the Guided Missiles division of Fairchild, Petrel is virtually a Mk 13 torpedo with an added wing, aerodynamic controls, a turbojet for air cruise propulsion and underwater radar homing. It was evolved from the Kingfisher and Grebe projects during 1949-1951. Produced until early this year by Fairchild at Wyandanch, N.Y., Petrel has now been superseded. It is operational on the P2V, P5M and (shortly) Argus, and is reliable and effective. Fuller details were given in our 1956 review.

**Rascal** An offshoot of the original Shrike programme, and conducted in parallel with the X-1 and X-2 series of research aircraft, Rascal has been a major responsibility of Bell Aircraft since 1946. Originally designated XB-63, it was the first weapon to bear the U.S. Air Force GAM (guided air missile) designation, retaining its original number. Bell have had complete management of the GAM-63 system since 1952 and have since been responsible for design, development and manufacture of the airframe, propulsion, guidance, ground-support equipment, launching gear, testing devices and training aids.

All the airborne systems are housed in the oval-section fuselage. In addition to warhead, guidance and accessory systems, the body is occupied by tankage for a rocket engine fitted with three superimposed aluminium-alloy chambers, each of which can be operated individually to provide thrust control. The propellants are reported to be nitric acid and petrol, although unsymmetrical dimethylhydrazine has also been employed. Lift and control are provided by upper and lower nose rudders, a fixed fore-plane fitted with elevators, a rear-mounted wing, also fitted with elevators, and upper and lower fins which fold sideways to facilitate ground or air transport. All horizontal trailing edges are blunt, and the structure is stressed for high accelerations at exceptional angles of attack.

Warhead yield can vary up to the largest sizes now envisaged, and nuclear charges are stated to be "pre-set." It is not known whether or not the warhead is designed to separate from the remainder of the missile, but it is believed that there are at least two phases of guidance: possibly launching, cruise and terminal. Initially Bell (Aircraft) radar command was employed, but the production weapon has inertial guidance by Federal Telecommunications Laboratories and Bell Aircraft (Avionics Division), with Model IIB accelerometers reading up to ±25g up to 350 c/s. Sonar-type radar is fitted in a radome beneath the nose.

About 40 XGAM-63s were launched during 1955-6, chiefly at Holloman from B-36s and B-47s. The latter type of aircraft is the only operational Rascal carrier. Installation of the GAM-63 system converts the aircraft to a DB-47, the weapon being accommodated on a pylon under the aircraft c.g. on the right-hand side; theoretically a DB-47 could have two such pylons, the Rascal wing tips almost touching on the aircraft centre-line. Contracts worth $7,273,176 and $14,767,294 were placed in January for further R. and D. and product improvement. This was unexpected, since the feeling was that Bell were working on a somewhat aged concept. In June the House Appropriations Sub-committee said they were trying to save money by eliminating "duplicative and questionable non-ballistic projects." They did not mean only Navaho; Rascal was named, and called "marginal."

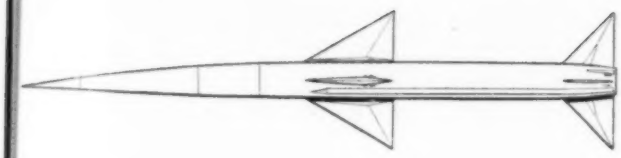
In the event this "marginal" system has won through, proving that a bird in the hand is worth having. The first production order came in August, and was worth $14m. The previous month cognizance for GAM-63 was passed from the A.R.D.C. to the Air Materiel Command, and pre-production rounds entered their final series of tests at Holloman. Four Rascals launched from B-47s (at unstated range or height), all achieved hits within a circle of 1,500ft radius. By October Bell's production line at Niagara Falls/Buffalo was full, and the first production GAM-63 was accepted at Pinecastle A.T.B. on October 30.

**Wag Tail** Likely to be required by the U.S. Air Force in very large numbers, Wag Tail (not Wagtail) is being developed under the management of the Minneapolis-Honeywell Aeronautical Division. It is a ground-attack missile which will be matched to supersonic fighter/bomber aircraft such as the later types of F-105 Thunderchief. It will have a warhead developed by the Honeywell Ordnance Division and inertial guidance of a relatively simple character, for which a sub-contract may be awarded to the Guided Missile Division of Republic Aviation.

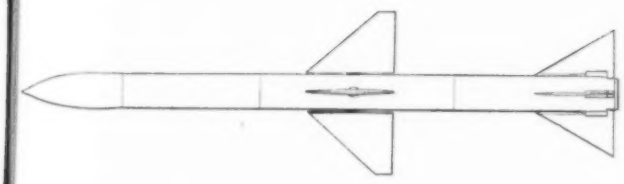
Early this year the prime contractor received an A.R.D.C. contract for $500,000 covering design, mock-ups, tunnel tests and evaluation at Eglin A.F.B. This study contract is in hand at the Minneapolis-Honeywell Missile Control Center in Los Angeles, but will probably eventually be centred at the company's $4.5m missile-guidance plant at St. Petersburg, Florida, which was opened in October.

**WS-131B** (name not yet allocated) This U.S.A.F. weapon-system designation identifies an advanced strategic missile of the "stand-off bomb" type. It is being designed to the requirements of the long-range bombardment aircraft of Strategic Air Command, in particular the Boeing B-52G. Compared with Rascal, already in service with that Command, WS-131B is appreciably simpler and has a longer range, the requirement of S.A.C. being put merely as "several hundred miles." The missile itself is GAM-77.

Responsibility for the development of this system has been vested in the Los Angeles division of North American Aviation, who were selected from twelve competing companies (possibly to soften the blow of the cancellation of Navaho, page 901). The U.S.A.F. accepted North American's proposal that the airframe should be the responsibility of the Missile



**Sperry Sparrow I AAM-N-2** Air-to-air. Solid sustainer motor. Length, 12ft 6in; body diameter, 8in; wing span, 27in; firing weight, 295 lb; burn-out speed, Mach 2.8; range, up to 5 miles.



**Raytheon Sparrow III AAM-N-6** Air-to-air. Solid sustainer motor. Length, approximately 12ft; wing span, 38.5in; firing weight, 350 lb; burn-out speed, about Mach 2.8.

Development Division at Downey and that guidance and allied components should be assigned to the Autonetics Division. The company have complete systems responsibility and the project is in charge of Dale Myers, previously chief engineer of M.D.D.

A drawing on page 897 gives a provisional indication of the configuration chosen. Supersonic cruise propulsion is provided by a single Pratt and Whitney turbojet, a surprisingly heavy and expensive engine for an expendable application. Turbojet propulsion was chosen in order to provide plenty of room for future growth of the missile, and the gross weight is probably of the order of 15,000 lb. During the past two months contracts have been formulated, and these are expected to total between $25m and $34m from FY58 funds. The contract will cover the development of the weapon only and it will have to be fully proven before production is ordered. The U.S.A.F. priority assigned to it is high.

## SURFACE-TO-AIR

**Antis** For almost a decade the U.S. Army, Air Force and various government agencies and other institutions have been conducting far-ranging feasibility studies into the problem of intercepting an ICBM warhead at a safe distance. Several programmes have been the subject of study contracts and a number of these were listed in our 1956 review. At present there are two major systems; one is an extension of the Army Nike system (Zeus) and the other is the Air Force Wizard system with an appreciably more advanced performance. These are described below. The key to the whole picture is the availability of tracking radars with an r.f. power of millions of watts yet capable of being kept at instant readiness. Recent demonstrations of Soviet prowess in the large-rocket field have thrown the whole picture of Antis into the limelight, and although Senator Symington said in September that "the idea that the anti-missile is around the corner or only five years away is absolutely false," tremendous forces are being marshalled to produce an operational system at the earliest possible moment.

**Bomarc** At present this is the only weapon in service in the western world intended for area defence—as distinct from point defence—against attacking aircraft of all types. Its genesis can be traced back to the pioneer work on ramjet propulsion conducted by the Boeing Airplane Co. in 1945-9. The history was outlined on p. 899 of our 1956 missile review.

As a programme for an operational weapon for the U.S. Air Force the work dates from 1949, and experimental prototypes were first fired in 1952. These were originally numbered according to the U.S.A.F. piloted-aircraft system as XF-99s, but were later redesignated IM-99 (intercepter missile). Several dozen YIM-99s have been fired from Patrick A.F.B., with increasingly good results.

Unlike most anti-aircraft missiles the IM-99 Bomarc has an aircraft-type configuration, and consequently has to bank before it can turn. The wing has a thickness ratio of about three per cent and a plan-form modified from a true 50-deg delta shape by tips cut off at the Mach angle. The entire outboard portion of each wing is pivoted to act as an aileron, and similarly the tip of the vertical tail and almost the entire horizontal tail surfaces are pivoted. Propulsive power is provided by twin Marquardt RJ43 ramjets, each of 28in diameter and with intakes of magnesium alloy coated with temperature-resistant paint. The RJ43 is now in full production at Ogden, Utah, against a $30m contract. Each engine is carried on a pylon beneath the cylindrical body and is fed from kerosine tanks which occupy the whole mid-fuselage section.

Launching of the IM-99 is truly vertical, from a special stand equipped with an elevating arm. Boost propulsion is provided by an Aerojet-General liquid-oxygen/kerosine rocket motor mounted in the tail of the fuselage. This motor has a single gimbal-mounted chamber, the pivoting of which provides flight control in the launching phase. There are no c.g. problems as the rocket propellants are burnt, since the flight-path is vertical. Later IM-99s will have a solid boost which can be jettisoned, thereby saving much dead-weight.

There are several guidance systems associated with this weapon. For the realization of its full theoretical value the IM-99 requires to be operated in conjunction with SAGE, the automatic electronic environment planned to cover the whole U.S.A. Radar guidance (Western Electronics Division) applied through SAGE, together with a computer (Remington Rand) and a ground/air data-link (Motorola) controls IM-99 to the vicinity of its target, whereupon the terminal guidance, comprising airborne active-homing radar supplied by the Westinghouse Air Arm Division, takes over. Transmitter and receiver dishes are located in the nose, the latter being a Pastushin glass-fibre/resin moulding which minimizes radar distortion. The Farnsworth Division of I.T. and T. is another major guidance contractor, who in April announced a $12m sub-contract for ground support and go/no-go operational test gear. Multiple control and accessory circuits are taken outside the cylindrical fuselage beneath a prominent axial fairing which starts in the guidance section and fades out into the fin. The warhead can be of the h.e. or nuclear type and it has an arming device by Erco.

Although the development to the operational configuration has been somewhat protracted, the weapon has achieved success. Earlier this year the U.S.A.F. decided to put it into the inventory of Air Defense Command and it is worth noting that it was probably the first weapon system to be purchased on the "time-phased procurement" policy which now applies throughout the U.S.A.F. In mid-May a contract for $7,109,195 provided for tooling and continued development, and the first inventory contract was placed at the beginning of Fiscal Year 1958, amounting to $139,315,444 (from FY57 funds). It has been suggested that Air Defense Command has completed inventory procurement of the F-104 and that the twenty squadrons of IM-99s which will begin to be operational late next year will replace that aircraft. A production IM-99 is calculated to cost $350,000.

Boeing were anxious to establish a separate division to manufacture the production IM-99 but, U.S.A.F. support for a new facility not being forthcoming, assembly operations are being conducted at Plant 2 in Seattle. Fully 70 per cent of the weapon system is sub-contracted, and production is building up rapidly (assisted by 100,000 sq ft of a facility taken over early this year from the Army Corps of Engineers). Boeing are still flying a B-57 with the first 17ft of IM-99 (including the complete airborne guidance system plus nitrogen and ammonia systems for cooling and pressurization) mounted in the nose and controlling the flight of the bomber. Numerous tests against target drones have taken place recently. Boeing achieved a spectacular "splash" of a QB-17 in mid-October, when an unarmed IM-99 was fired at Patrick A.F.B. (nearest control point more than ten miles from the pad), climbed to its operational height of 60,000ft, found the drone over one hundred miles from the coast, dived on it and destroyed it by impact. Current test programmes include: an investigation at Los Alamos and Arco into the effect of nuclear blast and radiation on the guidance transistors; testing undertaken by Boeing's Pilotless Aircraft Division in which airframes are being subjected to thermal testing in an oven; and bombardment with polyethylene pellets from a 0.22 rifle in simulation of flight through a rainstorm. At Harbor Island, Seattle, Boeing have established a training school, simulating a complete IM-99 base, which is now passing out personnel from the U.S.A.F. and sub contractors.

Several advanced versions of IM-99 are on paper and initial studies are being made with Boeing money. The increased warning time now available to A.D.C. units may lead Boeing to produce a super-Bomarc with high-energy "zip" fuel and greater range to meet the I.M.X. specification. Nevertheless, it is pertinent to quote Rep. Mahon who pointed out that complete IM-99/SAGE coverage "might run the total picture to $50B or 100B for the defense of the U.S."

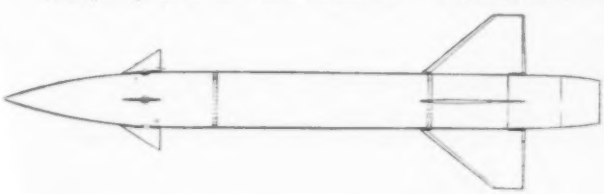
**Hawk** Developed for Army Ordnance by the Raytheon Manufacturing Company (under Redstone supervision), the Hawk system is complementary to the Nike system, with its capability of destroying low-altitude attackers. Compared with previous American anti-aircraft systems, Hawk is relatively simple and singularly mobile, being transportable by aircraft or helicopter and capable of deploying up to forward areas of a battlefront.

It is remarkable that Raytheon, an electronics company, should be prime contractors in two major weapon systems (the other is Sparrow III). Their guidance made the Fairchild Lark the first "Western" missile to destroy an aircraft. In recent weeks their Missile Systems Division has been moving to a new 40,000 sq ft office and laboratory at Waltham.

As the drawing (p. 898) shows, Hawk has a cruciform of one-piece cast wings, with about 80 deg leading-edge sweep, which are bolted axially to the body. The boat-tail fairing conceals four jacks which operate the hinged trailing-edge control surfaces. The external skin of the rear body is actually the wall of the solid-propellant sustainer, thus greatly reducing weight. Thiokol was the original powerplant contractor, but production Hawks have an Aerojet-General motor incorporating two solid charges in one chamber, the first being a rapid-burning portion to give high initial thrust.

Semi-active monopulse (Doppler ?) radar detects and tracks the target "in the blind spots of conventional radar." The lamp set has two dishes of unusual form, and is situated in the vicinity of the launcher. At the end of October the Army stated that the radar "can pick out reflection from a moving target at low altitude from a mass of signals reflected from ground objects." The missile itself has an ogival nose radome. Films have shown that Hawk can discriminate between numerous targets and pick on one previously selected.

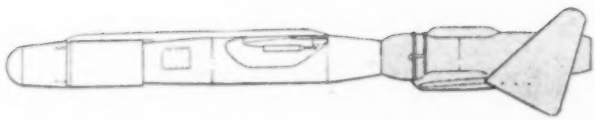
In October Northrop Aircraft (Anaheim Division) were awarded $20m for the development and manufacture of airframes. Northrop have responsibility for aerodynamic perform-



**Martin Bullpup** Air-to-surface. Solid sustainer motor. Length, 11ft; body diameter, 12in; wing span, 37in; launching weight, 600 lb; flight speed, about Mach 1.8; maximum slant range, reported to be 15,000ft.

# Missiles 1957 . . .

## (U.S.A.—continued)



**Fairchild Petrel AUM-N-2** Air-to-surface (air-to-underwater). Cruise propulsion in the air provided by a Fairchild J44 turbojet, underwater propulsion provided by Mk 13 torpedo machinery. Overall length, 24ft; wing span, 13ft; tailplane span, 8ft; launching weight, 3,800 lb; flight speed, Mach 0.7; range, 5 miles.

ance, a major proportion of the airframe, the mobile launcher, pallet and reusable container. A tracked vehicle carries three rounds at a time and loads them on to the launcher. About 40 acres are needed for a site, weapon storage being underground. Several locations have been selected, including areas around New York and Washington/Baltimore. Fire control of Hawk can be co-ordinated by the Missile Master. Last month the prime contractor received $35m for continued development and production, $6m of this being relevant to plant-preparation and tooling. Development rounds have been manufactured at Andover, Mass., and the complete Hawk system is now in pre-production, the Northrop components being planned for production at North Dighton, Mass.

**Nike Ajax** (originally Nike I) This famous U.S. Army anti-aircraft weapon is the most widely employed missile in the world, and is one of the few guided-weapon systems with which real experience suitable for statistical analysis has been acquired. Tens of thousands of rounds have been manufactured (over 1,500 were fired before the system became operational in December 1953) and total expenditure amounts to well over $500m.

A full history of the background to the development of Nike Ajax was published in our 1956 review. In retrospect it was probably a necessary evil to purchase this weapon in quantity, since, although it is of very early conception and has a system performance which falls short of that required to be certain of destroying modern bombers, it has enabled the U.S. Army to establish operational anti-aircraft weapon sites which will progressively improve as Nike Hercules and possibly later developments are introduced. The bulk of the enormous expense and effort required to introduce such a system to service, together with its associated electronic environment, storage and base-support facilities, training programmes and logistic supply problems has already been done, and numerous sites (40 were authorized in 1953 and most are now operational) are at present available for defensive purposes at an hour or two's notice.

Each missile has a cruciform of delta wings and a second cruciform of canard control surfaces arranged around the nose. The manufacture of the weapon has been described in some detail, and involves such novel processes as the use of "bubble gum" to reveal leaks in the 5,000 lb/sq in air pipes. Prime contractor for the overall system is Western Electric/Bell Telephone Laboratories, and Nike Ajax has always been manufactured by Douglas Aircraft, originally at Santa Monica and now at the Charlotte Ordnance Plant in North Carolina. Most of the structure is conventional, but the control surfaces are made of Douglas Aircomb, a Kraft-paper/phenolic honeycomb machined to very close tolerances.

The sustainer motor, by Bell Aircraft (originally by Aerojet-General), operates on nitric acid and kerosine fed through external pipes under the pressure of air stored in Menasco steel tanks. The single chamber has a rating of 2,600 lb thrust at 10,000ft and, being lined with Niafrax A ceramic, operates uncooled at 5,000 deg F and 330 lb/sq in absolute. Specific impulse is 212 and the maximum firing time 35 seconds. Major airframe sub-contractors have included Hamilton Standard, Kaiser and Rheem. The high-explosive warhead is surrounded by optimum fragments and has electro-mechanical fuzing by the Elgin National Watch Company. Eastern Industries supply hydraulic pumps and electronic-pressurization units. The whole assembly is fired vertically into the air by a solid boost motor by the Hercules Powder Company housed in a wrapped-steel casing by Goodyear.

As we stated in our 1956 review, the weakest link in the Nike Ajax system is its guidance (although this is improved in batteries modified to accommodate Nike Hercules). After the vertical launching and boost burn-out, the missile is steered by command guidance towards its target and is governed by a lead beam which follows tracking radars locked on to the target. Ground computation so controls the lead beam as to bring the missile to a pre-calculated position in space immediately beneath the nose of the attacking aircraft, whereupon the warhead is detonated through a command signal. In the defence of the metropolitan U.S.A. the weapon is associated with, and to a considerable extent controlled by, superimposed electronic systems which organize the whole operational structure of CONAD (Continental Air Defense Command). Chief of these is the SAGE (semi-automatic ground environment) and a second, more localized, system is the Missile Master developed by The Martin Company, which integrates the behaviour of a number of Nike batteries to ensure that no duplication takes place, neither is any target ignored. Such systems are not essential to the operation of Nike, and the weapon is already in operational service in such areas as Greenland, Alaska, and Germany where no comparable superimposed electronic environment exists.

Earlier this year the U.S.S.R. publicly denigrated the effectiveness of the system, basing their arguments largely on testimony offered to Congress by the U.S. Air Force who have long sought to prove that the weapon was obsolescent. The Army issued a prompt rebuttal, which included the statement that the guidance system "cannot be jammed." Wilbur Brucker, Secretary for the Army, recently announced that by the end of next year about 70 per cent of the active anti-aircraft battalions assigned to CONAD will be equipped with Nike. Typical of the strength of the installations are those around Philadelphia, where there are twelve sites, four of which were recently doubled in fire-power. The overall system is rather loosely described as "68 times as effective as conventional weapons." Other batteries are stationed at Thule, Greenland and four sites have been chosen in Western Germany. A site diagram was published on p. 900 of our 1956 review. Each battery has electronic equipment worth some $300,000 and containing 3,500 valves; these are not always "on the air" and must be allowed an adequate warm-up time.

No Nike Ajax missiles were procured from FY57 funds; 300 were cancelled on contract and it is anticipated that termination orders will be issued for 400 more. On the other hand, the Army has requested FY58 funds to rebuild approximately 4,000 Nike Ajax weapons, some of which have actually been in launchers for twenty months. Corrosion and deterioration of parts from exposure and repeated check-out operations have made the weapons non-operational, and it was stated that the cost of rebuilding Nike far exceeded that of conventional weapons "due to low densities, high component and parts costs and requirement for highly trained and skilled maintenance technicians." The Army stated that periodic rebuilding was essential to ensure precise calibration for effective firing.

**Nike Hercules** Pride of the U.S. Army, this impressive weapon, formerly known as Nike B, is the largest anti-aircraft rocket in the western world. Compared with its predecessor, Nike Ajax, it has a body with a greater length and much larger diameter, together with greatly improved guidance and much increased thrust. These improvements, together with large wings and a new control system, confer an operational performance claimed to exceed that of any other anti-aircraft weapon in the world (with the sole exception of Bomarc which has greater range). As a result, Nike Hercules can reach out and destroy any existing bomber before the latter could reach the point of release of a free-falling bomb aimed at the area protected by the missile.

Development prototypes had liquid-propellant sustainers, but production rounds have one of the new series of Thiokol solid-propellant motors which employ a new type of plastic-base polymer/oxidizer combination giving very high specific impulse. The boost unit comprises four Nike Ajax barrels joined at the front to a thrust casting and at the rear to a wrapping plate to which are attached four stabilizing fins. More than three-quarters of the length of the body is occupied by the cruciform of delta wings, which have acutely swept leading edges and are fitted with control "elevons" carried on projecting arms at the trailing edge. The latter surfaces are actuated by a control ring surrounding the sustainer motor tube, and the missile is stressed to manoeuvre with accelerations very much greater than the limits of the canard Nike Ajax.

Prime contractor is Western Electric, who manufacture ground and airborne guidance and control equipment at Burlington and Winston-Salem. It is possible to integrate Nike Hercules into the ground-control equipment of Nike Ajax after suitably modifying the latter (which also increases the effectiveness of the earlier weapon). The first production set of ground-guidance gear was released from Burlington at the beginning of the year and the equipment is now operational at several sites at present armed with Nike Ajax. Nike Hercules is described as "15 times as effective as Nike Ajax" and one Hercules battalion "armed with a nuclear weapon can deliver the equivalent fire-power of 40 anti-aircraft artillery battalions equipped with 90mm guns."

The radio-frequency power is reported to be in excess of 100,000 W and the missile itself undoubtedly incorporates some form of radar homing. It is noteworthy that the small axial aerials ahead of the wings are retained in the new weapon (they assist in damping out oscillation in flight) and it is possible that radar receiving equipment may be contained within the pointed nose. Two of the chief contractors for the warhead are Aerojet-General and Rheem. Current h.e. warheads embody new principles of fragmentation and incorporate a body structure of resin-bonded glass fabric. General Electric (MOSD) and W. L. Maxson are supplying electro-mechanical fuzing, arming and detonating systems. Next year the weapon will be available with nuclear warheads of five different yields, each costing in the neighbourhood of $1m.

As in the case of Nike Ajax, production has been assigned to Douglas Aircraft who have manufactured development rounds at Santa Monica and are now following-up these deliveries with bulk production at the Charlotte Ordnance Missile Plant, North Carolina. Douglas are also responsible for components of the associated launching equipment. The first pre-production ground equipment was released for test at White Sands Proving Ground at the beginning of the year and late in February it was announced that the complete weapon system was undergoing final testing. Wilbur Brucker, Secretary for the Army, stated in the summer that Nike Hercules had exceeded its design objectives and that it would shortly go into bulk production. Shortly thereafter General Maxwell Taylor, Army Chief of Staff, spoke of "six and eight cylinder Nikes to come" implying that there are yet more advanced versions.

It is still uncertain what form the final defence of the U.S.A. will take and at present Nike Hercules is competing with Talos for the point-defence role. It is hardly surprising that Lt. Gen. James M. Gavin, Army chief of research and development, recently said, "We will not abandon Nike Hercules as of this moment," since it represents a logical continuation of the overall Nike system which has been developed by the Army Ordnance Corps, Western Electric, Bell Telephone Laboratories and Douglas Aircraft for fully ten years, and represents an investment measured in billions of dollars. Moreover, the system may be capable of further improvement to operate against ballistic missiles, although this possibility is becoming increasingly remote (see below).

**Nike-Zeus** The U.S. Army attach great importance to this system, since it represents probably the ultimate phase of the whole Nike programme and loss of it would mean virtually the surrender of the defence of America to the U.S.A.F. at some future date. The missile

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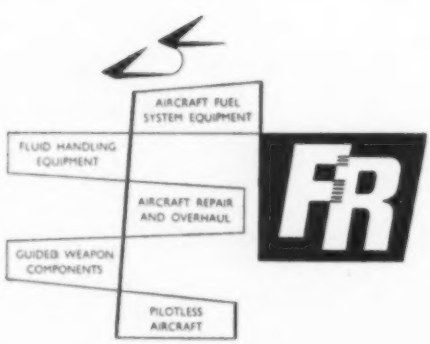


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TAC 11393

# Missiles 1957 . . .

## (*U.S.A.—continued*)

itself, originally called Nike II, is the farthest developed of any Anti; a logical improvement of the basic Hercules, it has a range of approximately 200 miles and exists in mock-up form. Prime contractors are Bell Telephone Laboratories (target location, acquisition, guidance and computer) and Douglas Aircraft. Late in October Western Electric (B.T.L.) received $5,086,481 for research and development of the system, but it seems clear that the fundamental brochure performance is inferior to that of the U.S.A.F. device.

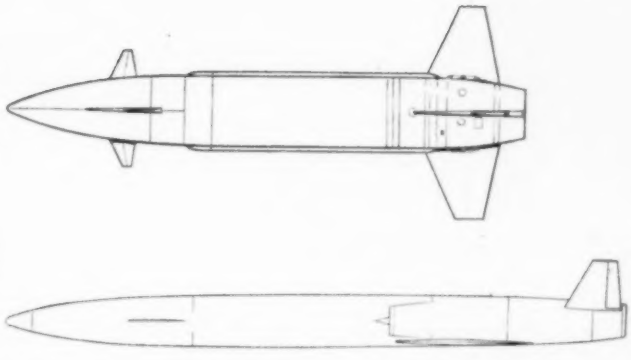
**Pied Piper** This weapon system of the U.S. Air Force is not intended to intercept a target; it is a reconnaissance satellite. Many agencies have conducted feasibility studies and general research into the military uses of satellites, but early last year the U.S.A.F. formulated a system (WS-117-L) for an "advanced reconnaissance system" taking the form of a satellite in an orbit between 300 and 1,000 miles up (and thus not "fixed" above a given part of the earth). Numerous companies are already involved, but that most heavily committed (and apparently acting as manager) is Lockheed Aircraft. More than $12m was invested in the first year of the Pied Piper programme; it is expected that an unmanned version could be ready by 1960 or shortly thereafter, with a manned version following some five years behind.

**Talos** This unusual weapon is the ultimate anti-aircraft missile stemming from the original Bumblebee programme of the Applied Physics Laboratory of the Johns Hopkins University. Compared with the hastily developed Terrier, Talos has better guidance and appreciably greater range owing to the fact that its sustainer motor is a ramjet. Prime contractor is the Bendix Aviation Corporation, who deliver complete rounds from the Naval Ordnance factory at Mishawaka, Indiana; a major sub-contractor is McDonnell Aircraft, who manufacture the ramjet and the bulk of the airframe.

As the drawing indicates, Talos is relatively fat, in order to accommodate the ramjet duct as well as the warhead, guidance and fuel tanks in the surrounding annular space. The control system is very similar to that of Terrier, there being a cruciform of moving wings together with a cruciform of fixed stabilizing fins at the rear, indexed at 45 deg to the wings. The fins are appreciably larger than those of Terrier to counteract the effect of the big fore-body, and in production the fin-material will probably be glass-fibre. The proximity-fuzed warhead can be either of the conventional or nuclear type, and it occupies the peripheral space between the guidance annulus and the integral tankage.

A large M.W. Kellogg solid boost motor accelerates the weapon off its launcher and takes it to ramjet-sustaining speed of well over Mach 1. At the burn-out point the boost casing drops off to the rear, thereby "unplugging" the ramjet propelling nozzle and allowing the sustainer to light up. Kerosine is fed through ram-air turbo-pumps located within the centre-body of the fixed-geometry, double-shock intake. R.C.A. is a major supplier of ground guidance gear, and, like Terrier, Talos rides a beam during the initial phase of its flight. Unlike the earlier weapon, Talos can switch to semi-active homing for a more accurate terminal phase, and in shipboard installations the "lamp" set is the big SPG-49 for which Sperry hold over $47m in production contracts. The weapon has eight flush strip aerials positioned axially around the nose, together with four probe aerials spaced at 90 deg around the lip of the intake. Farnsworth supply part of the ground test-gear.

Bendix received a $27m production contract from the U.S. Navy in February of this year and a further contract for $44m was placed from FY58 money to deliver additional evaluation quantities. In May Admiral Withington, Chief of the Bureau of Ordnance, stated that bulk delivery of evaluation rounds had begun and that intensive testing was in progress at White Sands, Point Mugu and from U.S.S. *Norton Sound*. Talos has been selected as the main armament of the light cruiser *Galveston*, which is scheduled to join the U.S. Navy in a few months' time, as well as of two other cruisers and the nuclear cruiser *Long Beach*.



**Bell Aircraft Rascal GAM-63** Air-to-surface. Three-barrel rocket motor for cruise propulsion. Length, 32ft; wing span, 25ft; launching weight, 13,000 lb; speed, Mach 1.6; maximum range, 100 miles.

**N.A.A. GAM-77 (WS-131B)** Air-to-surface. One Pratt and Whitney J52 turbojet for cruise propulsion. Approximate length, 40ft; launching weight, about 20,000 lb; cruising speed, probably about Mach 1.7; range, 500 miles.

White Sands testing demonstrated a degree of reliability so high that installation of the weapon in first-line ships has been accelerated. The General Electric Company have received a BuOrd contract for $5m for further development of the shipboard handling and launching system for the very advanced *Long Beach* (earlier ships have a Northern Ordnance system). The overall G.E. installation weighs 350 tons and will store complete rounds in pigeon-holes and will incorporate an electronic computing centre with which the fire-controller will automatically be able to select a nuclear or h.e. Talos and have it brought up and placed on the launchers completely automatically.

The original U.S. Navy Talos is SAM-N-6. An off-shoot of this is the land-based Talos system, which is under intensive development for both the U.S.A.F. and the U.S. Army. The former Service has Talos L which bears the U.S.A.F. designation IM-70 (Intercepter Missile). Strategic Air Command are likely to use IM-70 to protect their bases both within the U.S.A. and overseas. The Army weapon is Talos W and the first system, developed and built by R.C.A., was turned over to the Army for evaluation in October.

Under the roles-and-missions memorandum of November last year the Army is scheduled to evaluate the Talos system, but no decision has yet been reached. Eger Murphree, when he was co-ordinator of missile development, said "a careful study of the Nike Hercules and Talos developments has shown no predominant advantage for either system and there may be sound reasons for using both." Talos has been described as "cheaper than Nike" (presumably Nike Ajax), requires less operational man-power and can be installed with more flexibility; it does, however, require a great deal of electronic equipment, one report claiming that there are 250 separate cabinets involved in the ground check-out system.

**Tartar** Virtually a junior Terrier, Tartar has been evolved by Convair at Pomona as a smaller and simpler weapon for vessels too small to accommodate the full Terrier system. The round itself is about three-quarters as large as the unboosted Terrier and, although it has no booster motor, has performance approximately equal to its predecessor. The sustainer motor is a solid-propellant unit by the Allegany Ballistic Company, and guidance and control is largely handled by the Ford Instrument Division of Sperry-Rand. It is unofficially stated that the receiver dish for semi-active homing is housed beneath a Pyroceram (Corning Glass Works) nose which is being evolved at the Johns Hopkins University.

In May it was reported that the Tartar programme was "proceeding on schedule," and $32m was allocated from FY58 funds. Tartar will initially be fitted to eight U.S. Navy destroyers where it will replace 5in dual-purpose guns. As an example of the simplification of the system it is reported that "only about five avionic consoles are required for the search, track and fire-control as compared with approximately 20 for Terrier." Maximum flight speed is given as 1,500 m.p.h., and a production round should not cost more than $40,000.

**Terrier** As we recounted in our 1956 review, this highly developed naval anti-aircraft weapon is a rocket-propelled offshoot of the ramjet Bumblebee programme, initiated in 1945 by the Applied Physics Laboratory of the Johns Hopkins University. Terrier was originally an interim quickly developed weapon, but its wide adoption and good Fleet performance has insured it a permanent place. The system is designated SAM-N-7 and mass production began in January 1953 at Convair's new factory at Pomona, Cal.

From front to rear the missile consists of an ogive nose housing a high-explosive warhead, a forward guidance package containing hydraulic servos and four pivoting wings, a solid-propellant sustainer motor by M. W. Kellogg, and the aft guidance assemblies with rearward-facing aerials for riding a radar beam from the launching vessel. The rear fins are indexed at 45 deg to the wings and are fixed. Storage, loading and firing from a twin launcher is automatic, boost propulsion being provided by an Allegany tandem motor. Thompson Electronics manufacture the auxiliary power control, and for accessory power air is stored in an ellipsoidal forged-steel flask weighing 49.5 lb and tested to 7,500 lb/sq in.

All guidance is effected by riding the beam from the big SPQ-5 radar, for which Sperry hold over $51.5m in production contracts. Two such radars are fitted to U.S.S. *Canberra*, the second Terrier-equipped cruiser; the earlier *Boston* had Reeves radar. Either of the twin installations on these cruisers can direct a single launcher or a battery by "flexible modes of scanning the airspace many miles beyond the horizon," suggesting a link with A.E.W. radars. Reeves' experience on *Boston* has been put to good use on the simpler installation in the destroyer *Gyatt*, in which the radar carries out guidance and fire-control for a twin-Terrier launcher and for 3in and 5in gun armament. Terrier was first fired from a ship (U.S.S. *Norton Sound*) in September 1951. In addition to the three operational craft mentioned, the weapon is being installed in the new cruisers *Topeka*, *Springfield* and *Providence*, and the giant carriers *Kitty Hawk* and *Constellation* (for which Northern Ordnance hold two contracts totalling $20m), as well as a new class of frigate (DLG-14, *et seq*) and the nuclear carrier.

Production rounds cost about $62,000, Convair holding a fixed price (which has been criticized by certain naval spokesmen). Reliability of the weapon is good, and of more than 350 Terriers fired at N.O.T.S., China Lake, since 1954 about 80 per cent were described as "effective." Motorola, who are the second-source for guidance, have established the extraordinarily good tube-rejection rate of 0.5 per cent, probably one-twentieth of the national average. Nevertheless, airborne-guidance problems have been caused through vibration and unbalance in its cantilevered suspension, and in September Pomona began production of an improved Terrier incorporating new engineering features. Potting techniques and greater mechanical strength allow the revised missile to be handled as roughly as a 5in shell, and the producability of the new weapon has also been improved. For this round Pomona is handling all the guidance (no second-source), the contract for $29m being placed in December 1956.

Terrier II is described as a "double-size" weapon with active-homing radar. No details are yet available, apart from the fact that it is intended particularly for frigates and similar craft too small to mount an SPQ-5 installation, and that the missile has a nose of Pyroceram to resist heat and thermal shock yet transmit radar waves.

**Wizard** Under this name an extremely broad programme for an overall defensive system for the entire American continent has

# Missiles 1957 . . .

*(U.S.A.—continued)*

been planned for several years by Convair and the Radio Corporation of America. The U.S.A.F. awarded Phase I studies to Boeing/G.E./Ramo-Wooldridge, Lockheed/Raytheon, and Douglas/B.T.L., but Convair/R.C.A. are the only group going ahead with the work and their system has been endorsed by the Joint Chiefs of Staff as the future defensive system for the whole of the U.S.A.

Fundamental to the successful interception of any ballistic warhead is its early detection, and the "break-through" which has made the Wizard concept practicable is the development of "fine structure analysis" radar by Columbia University and Rome A.D.C. since March 1954. This permits target range and velocity to be measured with unprecedented accuracy even when the signal strength is still below the (unprocessed) background noise level. Existing radars can see up to 300 miles (one minute's ICBM flight), but the Columbia Omnirange Digital Radar extends this to fifteen minutes, a distance of some thousands of miles. The intention is that the Wizard anti-missile should meet the on-coming ICBM near the apogee. The missile itself will have a nuclear warhead and a range of approximately 1,000 miles and a flight performance appreciably in advance of that of Hercules. Our American contemporary, *Aviation Week*, states that sub-contractors on Wizard are: G.E. (MOSD) for the warhead; Sanders Associates for a special multi-lobe aerial system, resistant to point-source jamming; D. S. Kennedy, Inc., for research into large parabolas; and Avco for aerial steering devices.

## SURFACE-TO-SURFACE

**Atlas** As the first intercontinental ballistic missile in the Western world, this weapon has required an unprecedented amount of fundamental research into previously unexplored realms of science. It is logical that a very great deal of the work carried out for Atlas, as well as numerous items of "hardware," should have been carried across to accelerate progress with the later Titan and Thor.

A full account of the background to the genesis of Atlas was given in our 1956 Missiles issue. The original U.S.A.F. project number was MX-1593; the weapon-system number is WS-107A-1, the missile itself is SM-65A (Strategic Missile) and to Convair, the prime contractor, it is Model 7. Initial design and prototype fabrication was done at Convair's San Diego division, but during the past few months it has been transferred to a completely new $40m facility north-east of San Diego. The headquarters of the Astronautics division, this plant will be fully occupied by the middle of next month with a staff of 7,000. Chief project engineer is Charles S. Ames.

One of the areas in which the design of the Atlas has broken new ground is that of airframe design. Unlike the Army ballistic missiles, Atlas has an airframe with a skin so thin that the interior (integral tanks) has to be pressurized in order to preserve the shape of the body as the propellants are consumed during flight or when the missile is being transported on the ground. Structure weight has thus been minimized and the mass-ratio is better than that of any previous ballistic weapon.

Prime contractor for propulsion is North American's Rocketdyne division. There are three powerplants, arranged in a unique fashion. The main body comprises integral tanks for JP-4 fuel and liquid oxygen, and these propellants are fed by turbopump to a single gimbal-mounted chamber, rated at 65,000 lb thrust, mounted centrally at the lower end*. On either side of this motor is pivoted an additional single-chamber motor rated at 135,000 lb thrust, providing boost propulsion. These boost motors burn for 180 sec and are then jettisoned as a package, taking the large flared body skirt—which provides increased directional stability—with them. All three motors are fired on the ground, so that Atlas can reasonably be called a "1½-stage missile."

Following cancellation of the ballistic A.C. "Achiever" system, prime contractor for guidance is General Electric, whose Heavy Military Electronic Department (Syracuse) received an $83m contract in April to continue this work to the production stage (the H.M.E.D. guidance section is unique in that it conducts its own design, manufacturing, selling, finance and employee relations). The system is of a hybrid radio-inertial variety, functioning in conjunction with G.E. ground radar of very high power, together with a Burroughs computer. Such a system does not require a true inertial platform, and a contract originally let to Minneapolis-Honeywell was therefore cancelled. The latter firm's HIG floating gyros are, however, proving so reliable that the final Atlas guidance may well be the pure-inertial system developed for Titan (*q.v.*). The guidance controls the trajectory solely by changing the axis of the sustainer motor.

Third of the major problems of any ICBM is the nose cone, and here again the prime contractor is General Electric (in this case the Missile and Ordnance Systems Division). A contract for $158m was agreed for this work and the nose-cone section of MOSD have evolved a curious design with a very smooth nose of some 3ft radius, faired into a corrugated re-entry body about 6ft deep with a metal base coated with special laminated plastic (here again, this may not be the final configuration). Such is the pace of development that 3-4 days is the maximum allowed for processing the 300 types of information available from each nose-cone test, and MOSD Philadelphia operate a $3m automatic computation facility equipped with an I.B.M. 704 and auto analogue/digital converters and switching equipment. Tape containing data from nose-cone tests by government and industrial centres—and, now, from flight tests—are handled with unparalleled speed and reports are then made up for the 1,100 MOSD scientists involved. A sub-contractor for assembled nose-cone hardware is Republic Aviation's guided missiles division.

Contractor responsible for the warhead is the Sandia Corpn., a subsidiary of Western Electric. The warhead will weigh at least 3,000 lb and will, of course, have a megaton yield and very advanced fuzing. The electrical system is energized by an A.M.F. (American Machine and Foundry) turbo-alternator running on the main liquid-oxygen/fuel mixture. Gas pressure for the propulsion system is obtained from a manifold fed with the products of combustion of a controllable cartridge. As the drawing indicates, a number of pipes and controls are run outside the liquid-oxygen tank in a faired conduit.

Convair hold a $145m contract for airframe fabrication and testing. Twelve XSM-65s are reported to have been manufactured at Plant I in San Diego. The first was static tested at the Convair facility in Sycamore Canyon (p. 883) in March of this year. Component testing is handled by a facility on Point Loma—also near San Diego—and further ground tests, including static firing, are being undertaken on Leuhman Ridge, within the perimeter of Edwards A.F.B. No aircraft can reasonably carry Atlas and all are at present being moved on 35ft steel-tube trailers, provided with elevating rams for placing the empty missiles on their tails. Each trailer has electronic test-gear by Hallamore (Siegler Corpn.). Tank pressure-tests are carried out vertically in *ad hoc* buildings.

The first XSM-65 to reach the firing pad at Patrick was scheduled to be launched on May 29, but it was delayed by malfunctioning ground-gear until June 11—by which time static-firing time had reached 700 sec. The first flight-prototype comprised an airframe with a simple, pointed nose, together with the two boost motors: absent were the sustainer and the operational guidance system. Simple programmed guidance was incorporated to keep the Atlas climbing to a height of 400 miles (long after burn-out) followed by a controlled flight to a point 200 miles distant.

Pre-flight checks on June 10 were satisfactory and, following a 10½-hour count-down, the prototype was fired on June 11. Ignition was good, as was thrust-balance between the two motors. After only a few seconds, however, a failure to a turbopump valve almost completely shut off the liquid-oxygen supply to one motor. The flame from this side changed from yellow to a dirty orange, leaving a long smoke trail of burning fuel. The sudden loss of thrust on one side caused a violent yaw; a complete loop followed, after which the hard-pressed guidance effected some correction by fully gimballing both motors. Yet vertical flight could not be held, and two more loops followed, until finally the erring vehicle was detonated by Patrick's range safety officer. The flight ended at about 6,000ft, after 32 seconds' firing time (10 on the pad and 22 in the air). Telemetry was perfect and 95 per cent of the programmed data was actually obtained. Moreover the Atlas proved that its airframe could withstand lateral accelerations of up to 22 g—an incredible demonstration of structural strength outside any original design case.

A second flight-test was conducted on September 25. On this occasion all three engines were installed, and a curious flight-plan was programmed: vertical climb for a few seconds followed by push-over at 15,000ft and level flight at that extremely low altitude for 2,000 miles down-range until detonation over the outer Bahamas. Such a flight was scheduled to produce aerodynamic data required for advanced testing. In the event, a malfunction—presumably similar to that of the first prototype, since there was an excess of fuel—led to detonation as soon as cruising height was reached. Once again telemetering was perfect and valuable information was gained.

Production SM-65s are beginning to take form in the new factory. Each will probably be priced at about $1m, exclusive of weapon-system supporting equipment, which is about half the cost of any of the prototypes. Atlas motors are manufactured at Rocketdyne's new facility near Neosho, Missouri. Turbopumps built there went on test in September, and the first production Atlas powerplant began static trials last month. This proved the stands, and current running is on a normal production-acceptance basis.

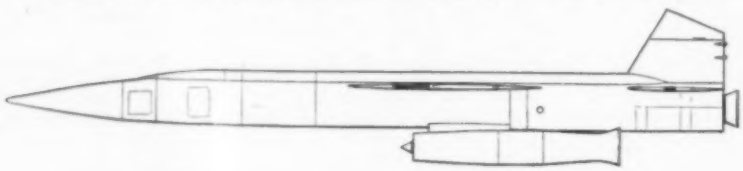
Total SM-65 programme costs now amount to more than $500m—a relatively very modest figure. It will probably be the first ICBM in service in the West, the schedule being 40 operational SM-65s on the pads of Strategic Air Command by 1959. It is, however, pertinent to point out that an SM-65 is a very tight fit in a C-133A transport (no other aircraft can take it), and that trucking a single weapon from San Diego to Patrick takes 10 days. Much must be done before it becomes operational.

**Corporal** This lofty spindle of a weapon is probably so well known by now that little need

* *All descriptions of ballistic, tail-standing weapons are worded to conform with the missile in the vertical (firing) position.*

**Raytheon Hawk** Surface-to-air. Solid internal boost and sustainer motors. Length, 16ft 4in; span, 47in; body diameter, 16in; firing weight, rather more than 1,000 lb; burn-out speed, more than Mach 2.8; slant range, about 15 miles.

**Boeing IM-99 Bomarc** Surface-to-air. Liquid-propellant boost motor with gimbal-mounted chamber (retained on board) and twin Marquardt RJ43 ramjets for cruise propulsion. Length, 46ft 8in; span, 18ft 2in; body diameter, 36in; launching weight, 15,000 lb; cruising speed, Mach 2.7; ultimate range, over 250 miles.



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## Missiles 1957 . . .

### (*U.S.A.—continued*)

be said about it. A specification appears beneath the drawing and a full history of its development was published on p. 904 of our 1956 review.

From the top downwards, Corporal comprises: a pointed nose carrying a kiloton warhead; a package containing radar/Doppler guidance; a polygonal section housing 2,350 lb/sq in air tanks; large tanks of red fuming nitric acid and xylidine; and a fixed Ryan-built rocket chamber, together with cruciform fins, controls and small vanes in the rocket jet. Prime contractors for this weapon are Firestone, for the airframe, and Gilfillan (assisted by Motorola) for the guidance. The basic design-work was undertaken by the Jet Propulsion Laboratory of CalTech. Extensive details of the complete weapon system, including notes on ground equipment, firing drill, performance and operational history, were published in our 1956 review.

**Dart** Although appreciably larger, and far more expensive, than the French S.S.10/11 and British Vickers 891 weapons, the U.S. Army's Dart is designed for a similar function: delivery with pin-point accuracy of a warhead capable of knocking out the heaviest tank known. The basic development of the SSM-A-23 system was handled by the Army Ordnance District, Los Angeles; Redstone Arsenal; and the Aerophysics Development Corporation (of Santa Barbara, Cal., a subsidiary of Curtiss-Wright).

Within the body are a large, shaped charge and a smokeless, solid-propellant rocket sustainer motor by Grand Central Aircraft. The weapon is fired from a zero-length launcher, usually mounted on an M59 truck, and its operator guides the weapon by keeping it, or sodium flares fixed to it, aligned with the target. This he does with the aid of an optical tracking system by the H. A. Wagner Co., which is connected to the launcher by a cable. Although no details have been released, it seems probable that the motor has a high-thrust initial portion to provide requisite acceleration at launching. The initial guidance is simple gravity-correction by gyros (it was no easy task to find a suitable non-electric gyro), presumably operating the hinged trailing edges of the wing cruciform. In-flight guidance is probably effected by means of small spoilers at the wing-tips, since the steady speed is almost sonic.

Dart has many times demonstrated very accurate guidance, going through, or very close to, the bull on 6ft cloth targets at ranges well over a mile. Production is being undertaken by the Utica-Bend Corpn., a subsidiary of Studebaker-Packard (and so also of Curtiss-Wright). The first production contract, placed in August 1956, amounted to $16,565,000, and inventory deliveries are now being made to the Army. Stanford Research Institute have a $97,000 assignment to analyse Dart production and formulate budget control for the system. Late in October the Aerophysics Development Corporation received a $403,036 contract for further Dart development.

**Goose** Also known as Bull Goose (or Blue Goose), this name refers to a U.S. Air Force family of peculiar character. Bearing the weapon system designation WS-123A, the missile itself is SM-73 and the prime contractor is the Fairchild Engine and Airplane Corporation who have expended their facility at Hagerstown to undertake this work.

The designation SM-73 (strategic missile) suggests that the missile portion of the system takes off from the ground, although it has been suggested that it is carried aloft by a B-58 or similar aircraft. The airframe is of an aircraft-type configuration and its function is purely diversionary; in particular, it is designed to act as a decoy for surface-to-air missiles, and to this end carries a radar transponder of the corner-reflector type.

The basic SM-73 is reported to be manufactured largely of resin-bonded dielectric material. For ground launching, a Thiokol solid boost motor is provided and cruise propulsion takes the form of a single Fairchild J83 turbojet of about 2,200 lb thrust, which is stated to give a cruise Mach number of about 1.25 (a curious figure, which must result in poor specific range). Fairchild radio-command guidance is reported to be matched with a Kollsman flight-control system so that—presumably—the vehicle can be steered from the ground or from a parent aircraft. No details of the configuration have been revealed, but the span has been given as about 13ft and the length variously as 20ft and 30ft. Maximum operating altitude has been placed as high as 100,000ft, which seems excessive in view of the nature of its powerplant.

One of the few things which can be deduced with assurance is that the range must be well over 500 miles, otherwise the "SM" designation would not be applicable. One report states that the Goose family "includes parallel development of the Duck missile"; the latter weapon, although reported to be an air-to-air missile and described in that section of this issue, is also described as a surface-to-surface device; our American contemporary *Missiles and Rockets*, says of Goose and Duck "while essential elements . . . are similar, airframes are different in size and some aerodynamic characteristics." Altogether Fairchild seem to have a curious series of offspring in the Goose family which was reported in July to be in preliminary production. In a recent list of published contracts WS-123A was named as a weapon system for which the J. C. Harper Construction Company were to build "complex 21 and support items."

**Honest John** Although not guided, this tactical army support weapon is otherwise characteristic of the overall missile family. It is a large-calibre rocket, mounted and fired from an elevating ramp carried by a vehicle and deployed up to forward battlefield areas. The weapon is aimed in artillery fashion and thereafter follows a free-flight trajectory.

Propulsion is provided by a solid sustainer with a 2,000-lb (weight) cast charge by the Hercules Powder Company. For stability the weapon is spun at launching by four small tangential rockets behind the warhead, the spin being maintained by the canted fins. Many thousands of rounds have been delivered from Douglas Aircraft and Emerson Electric, Alco fabricating the bodies from steel sheet. With a 1,500-lb warhead, maximum range is achieved at an elevation of 50 deg, reaching a trajectory peak of 30,000ft in 41 sec and a strike at 30,000 yd in 87 sec. Training courses are simple, and the weapon is likely to be employed by the NATO countries and Japan.

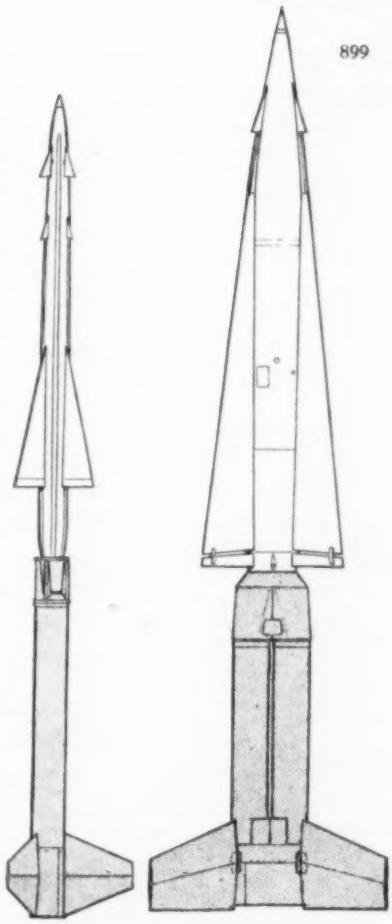
**Jupiter** This IRBM (intermediate-range ballistic missile) has been, and still is, the focal point of one of the greatest political storms ever to afflict the development of any weapon. It is the product of the Army Ballistic Missile Agency at Redstone Arsenal, under a design team led by the renowned Dr. Wernher von Braun (creator of the A-4, or "V-2" weapon), who is A.B.M.A's. director of development operations. It is a natural and logical outcome of the arsenal's successful development of the earlier Redstone.

In November 1955 came the famous—or infamous—memorandum by Charles Wilson, then Defense Secretary, on the roles and missions of the Army and Air Force. This document laid down that the responsibility for all land-based weapons with a range greater than "about 200 miles" should be vested in the Air Force. Although the Army were allowed to make limited feasability studies into systems beyond the 200-mile limit, the memorandum orphaned Jupiter completely, and decreed that, even if it were perfected, the Army would not be permitted to operate it. This may have been a blunder of the first magnitude. What certainly was an unforgivable decision was that which placed in the Air Force's hands responsibility for the financing and development of all long-range weapons. When the appropriations for Fiscal Year 1958 were reviewed the U.S.A.F. made no provision for Jupiter, thus somewhat pre-judging the issue. But it is advisable first to describe the missile itself.

Like its hastily developed competitor Thor, Jupiter is a single-stage weapon, powered by a gimbal-mounted Rocketdyne S-3 motor, of some 150,000/160,000 lb thrust in current versions; combustion pressure is held constant by a Servomechanisms controller. Unlike the Air Force weapon it has a relatively conventional airframe, of constant diameter, topped by a quite different type of nose-cone and devoid of fins. It follows that all stability and guidance is effected by pivoting of the S-3 chamber. For many years Sperry have been improving the air-bearing gyros of the German A-4 missile, and gyros with air bearings are used in the inertial platform of the Jupiter guidance, which is by the Ford Instrument Co., a Sperry-Rand subsidiary. As a backstop a radio-inertial system has been evolved, and the chief electronics sub-contractor is Motorola (Western Electronics Division). The J.P.L. CalTech team have also contributed much to the Jupiter system, all these contractors having gained great experience with Corporal and/or Redstone.

In contrast to the U.S.A.F., who hurried through the evolution of Thor on a maximum-risk basis, the Army have developed Jupiter with extreme care, proceeding cautiously from one stage to the next. The earlier Redstone weapon has been very widely used as a test vehicle, and as many as possible of its actual components have been carried across to Jupiter wherever this could be done without impairing the latter's performance. Recently Dr. von Braun stated that this meant that "a great number of components" of Jupiter were "therefore tested and proven."

First vehicle to bear the name Jupiter was a specially instrumented species of Redstone designated Jupiter A. Several of these were fired from Patrick A.F.B. during 1956, and the later examples incorporated actual components or portions of the final Jupiter. Six Jupiter A vehicles were given an increase in range to 800 miles. Concurrent with the firing



**Douglas Nike Ajax SAM-A-7** (Left, above) Surface-to-air. Solid boost motor, liquid sustainer. Overall length, 34ft 10in; length without boost, 19ft 9in; body diameter, 12in; foreplane span, 24in; wing span, 63in; firing weight, without boost, about 1,100 lb (300 lb warhead); burn-out speed, Mach 2.28; slant range, 10 to 25 miles.

**Douglas Nike Hercules** Surface-to-air. Quadruple solid boost motors, solid sustainer motor. Overall length, with boost, 41ft 6in; length of basic missile, 27ft; span, 74in; maximum body diameter, 25in; firing weight of missile without boost, approximately 5,000 lb; burn-out speed, about Mach 3.3; maximum slant range, of the order of 68 to 75 miles.

# Missiles 1957 . . .

## (*U.S.A.—continued*)

of these vehicles was a second programme, intended to investigate problems associated with re-entry of the Jupiter nose-cone and warhead—which, like Redstone, separates from the main body. For this purpose the A.B.M.A. evolved Jupiter C, a towering three-stage device comprising a single Recruit (solid-propellant test vehicle) bearing the nose-cone, standing on a cluster of four Recruits, in turn mounted atop a Redstone propulsion section. One of these Jupiter C vehicles was fired from Patrick a distance of 3,300 miles, easily beating all previous records for speed, distance and altitude, as far as the "western nations" are aware.

No precise time-table of the flight-trials of the real Jupiter can be compiled at this time, but it is known that the first two development prototypes were launched from Patrick in the early spring of this year. Neither achieved a successful flight, and it is unofficially reported that both exploded before burn-out as a result of structural failure caused by sloshing of the kerosine and/or liquid oxygen. The third Jupiter was carefully re-engineered to prevent a repetition, and the integral tanks were provided with special sets of baffles evolved by the A.B.M.A. (not by the U.S.A.F. as one report averred) and designed to minimize sloshing without interrupting fuel flow. In addition two other potential sources of trouble were investigated: the gust-sensing indicator was removed from the forward probe, and the base of the weapon was redesigned to incorporate a heat-shield to protect the control wiring from eddies of flame from the rocket motor during the first few seconds of firing.

When this third Jupiter was launched in May it performed admirably in all respects, achieving a range of some 1,500 miles and a peak altitude of between 250 and 300 miles. This proved the ability of the weapon to reach its full design performance, and the knowledge put new life and inspiration into the A.B.M.A. workers and Army "top brass," most of whom were despondent at the manner in which their IRBM was being taken from them and possibly shelved. The third prototype consisted of the final airframe and nose-cone, together with the definitive S-3 motor. In place of the warhead was a ton of instrumentation, and instead of guidance the vehicle was controlled by an autopilot pre-programmed to follow the optimum trajectory. Like current Jupiters, this round had an accessory-power unit energized by combustion of the main propellants, with water governing turbine temperature; earlier Jupiter A.P.Us. had employed H.T.P. The drawing shows the exhaust stack in the base-plate serving both the A.P.U. and the main rocket turbopump.

By August the Army were firing Jupiters equipped with a representative guidance system. One of the firings (there were at least two) in that month concerned a vehicle described as a Jupiter C, but in all probability really a Jupiter development round. This well-trained missile reached an apogee at 400 miles, a re-entry velocity of 12,000 m.p.h. and landed within a previously determined 400yd circle. The Army claimed that the round "posted a letter" to Gen. Medaris, commander of A.B.M.A., which was actually recovered from the Atlantic ocean. The nose-cone, reported to have been non-metallic, was proudly displayed to the world by President Eisenhower. Certainly the Jupiter guidance has many times demonstrated high reliability—as, in fact, has the entire weapon.

In recent months the relations between the teams actually working on the Army and Air Force IRBMs have been satisfactory, and both Douglas and the A.B.M.A. have visited each other (as a result of which the Army weapon may soon appear cloaked in a more sophisticated airframe). The elimination of Jupiter from FY58 funding was initially countered by the intervention of the Defense Secretary, and it is believed that in August a small allocation was made to the programme from the Defense Emergency R. and D. fund. Shortly before that time the Defense Department removed from the Air Force the responsibility for financing the development of Jupiter, and according to the *Montana Democrat* the programme has actually received about $35m from FY58 funds. Early in October the total investment in Jupiter was reported to have reached approximately $200m.

Should Jupiter be produced in inventory quantity for the U.S.A.F. Strategic Air Command it may be manufactured by the Chrysler Corpn., who have handled all production of Redstone and are exceedingly conversant with Jupiter. Production would probably be undertaken in Detroit, but there has been talk of a $300m Chrysler production plant being established near Redstone Arsenal—which seems exceedingly unlikely. The cost of a production Jupiter has been estimated unofficially at $480,000.

As it stands, therefore, the Jupiter programme may produce a Jupiter, or a Thupiter/Thorpiter, or possibly nothing. Some relevant quotes are: "nothing succeeds like success in this business" and "you can't expect to win anything with pieces of paper" (a dig delivered by Chrysler at the performance of Thor); "Jupiter is an isolated hardware program without production, training and operational back-up" (*Aviation Daily*); "If the Jupiter is the best missile, and, from what I hear, it is, I would favor going ahead with it" (Sen. Henry Jackson); and "The Jupiter program will be continued through its test program" (Neil McElroy, the new Defense Secretary). In October, when news of the postponement of plans for "marrying" Jupiter to Thor reached Redstone, overtime was once more allowed at A.B.M.A. and the Jupiter went full-steam-ahead again.

**Lacrosse** The genesis of this system was a Marine Corps study in 1947 for a weapon capable of being fired against the largest hard-skinned targets—major fortifications—from ground bases and helicopters. Cornell Aeronautical Laboratory and the A.P.L. at Johns Hopkins co-operated in a feasibility study, and Cornell were awarded an R. and D. contract in 1949. Shortly before the Korean war began the project was reoriented as an Army programme, and Cornell were given a high-priority development contract. Early in 1956 The Martin Company were brought in to assist in final development and undertake production.

Configuration is unusual, there being cruciforms of fixed, swept wings and unswept movable tail surfaces. Federal Telecommunications Laboratories supply radar command guidance, but Cornell were reported last July to be investigating a more self-contained system, less open to countermeasures. Pesco Products division of Borg-Warner supply the hydraulic control package. The large warhead is by Honeywell's Ordnance Division, and has fuzing and arming by General Electric's MOSD. Propulsion is effected by one of the new range of high-impulse solid sustainers by Thiokol; the charge has a synthetic rubber oxidizer base, and is one of the largest such motors to reach the production stage.

Martin manufacture a high proportion of the complete Lacrosse system, including the cantilevered-tube launcher, which is mounted on a pivoting base carried by a standard 10-wheel lorry and has a hydraulic jack to elevate the missile to the required firing angle. All elements of the system are mounted on mobile carriers, and the bulk of it is air-transportable by small Army aircraft. The actual guidance unit need not be close to the launching point, and would normally be in an extreme forward position. The target need not be visible provided its co-ordinates are known; thus the system is unaffected by weather.

Development Lacrosse weapon systems were very successfully tested at White Sands P.G., New Mexico. These missiles were in pre-production at Baltimore when, a year ago, the programme was transferred to the new interim 488,000 sq ft plant at Orlando, Fla, which cost $6,031,950 and now employs almost 3,500. Production Lacrosse systems are of an improved type, and the first came off the Orlando line at the beginning of August. Overall cost of the programme is described as "one of the lowest in missile-systems history." In service the Lacrosse will provide "one-shot" demolition of any enemy strongpoint, more surely and more cheaply than by artillery or fighter/bombers.

**Little John** This simple and effective weapon was evolved by the Rocket Development Laboratories at Redstone Arsenal between February and June 1956, being test fired in the latter month. Compared with the larger Honest John, it is more mobile, particularly under the most adverse operational conditions. Although described as a free-flight weapon, it has movable fins each carrying a tracking flare (suggesting that the weapon is actually guided by radio command).

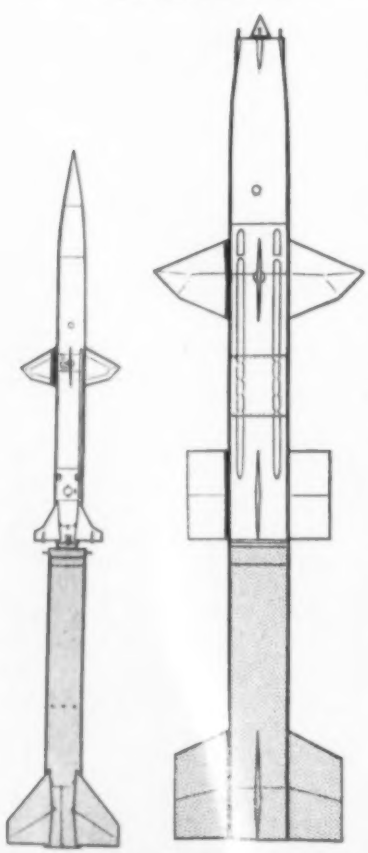
All the systems development was done at Redstone, and the following companies and agencies contributed: Allegany Ballistics Laboratory (propulsion charge); Consolidated Western Steel (sustainer case and chamber); Emerson Electric (airframe); Rock Island Arsenal (launcher); and Picatinny Arsenal (warhead). Intensive training and indoctrination is at present taking place and the weapon is beginning to go into U.S. Army service. Part of the production is being undertaken by Douglas Aircraft, and the warhead is supplied by the Honeywell Ordnance Division, with arming and fuzing by G.E. (MOSD).

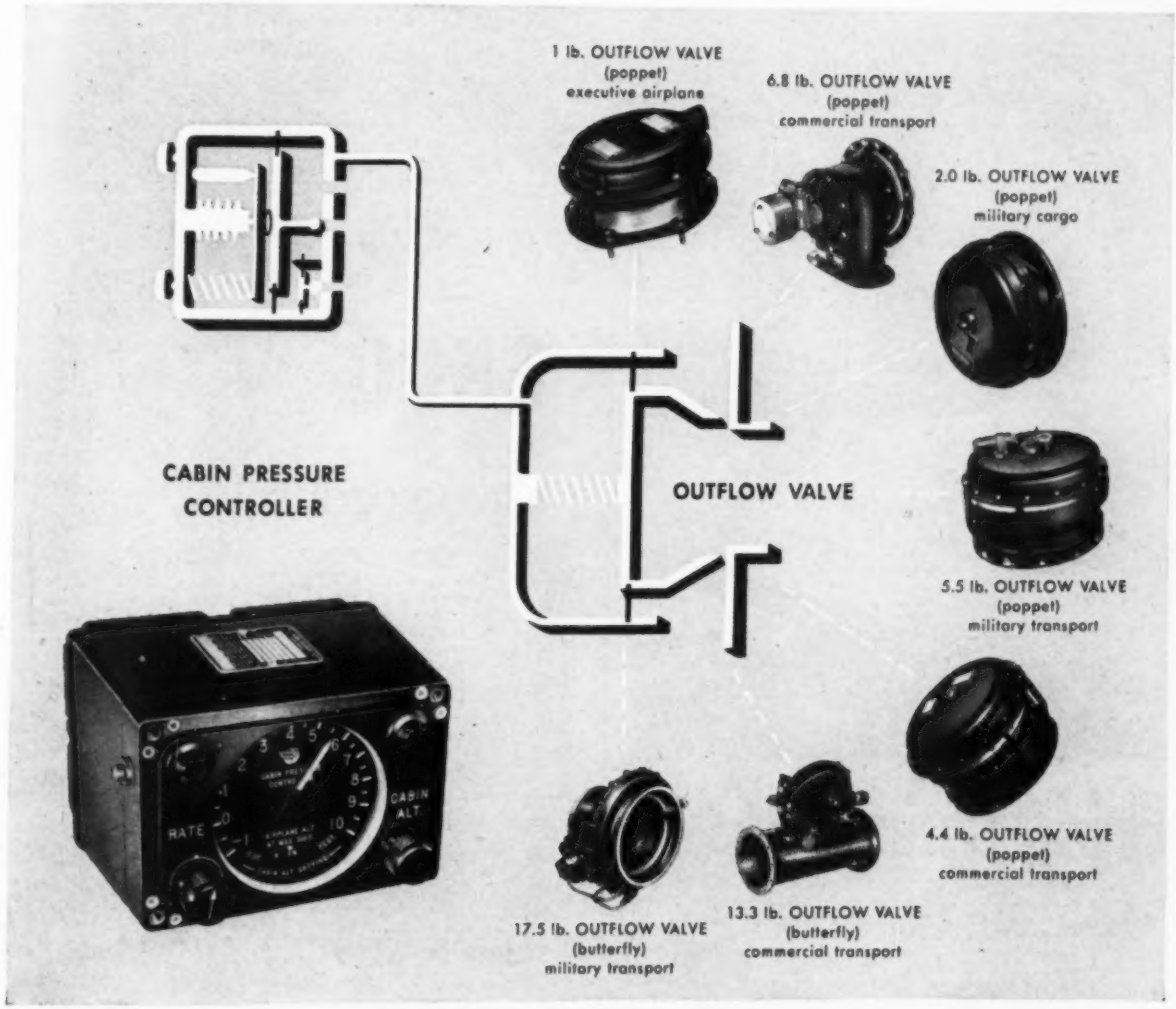
**Matador** Apart from the "V-1" of 1944, the U.S.A.F. Matador was the first pilotless bomber ever to go into large-scale service, and it has now branched out into a highly effective family of weapons which are at combat readiness in various parts of the world. The basic TM-61A was fully described in our 1956 review, in which was published a history of its genesis and development and full details of the manner in which a squadron equipped with it operates in the field.

TM-61A, as the basic type of Matador, is a high-wing aircraft comparable in size with a modern fighter and manufactured by The Martin Company in Baltimore, using a cheap and effective metal-honeycomb structure for major airframe components. Complete interchangeability was achieved soon after production began early in 1954, and since that time production missiles have been shipped unassembled in crates, for erection by the user squadron. The weapon is fired from mobile launchers with the aid of a large solid boost

**Bendix Talos SAM-N-6** (Below, right) Surface-to-air. Solid boost motor, integral ramjet for sustainer propulsion. Overall length of missile and boost, about 31ft 3in; length of basic missile, 20ft 3in; wing span, about 95in; body diameter, 29.5in; firing weight, without boost, approximately 3,000 lb; maximum slant range, of the order of 38-40 miles.

**Convair Terrier SAM-N-7** (Below, left) Surface-to-air. Solid boost motor, solid sustainer motor. Overall length with boost, 26ft 5in; length of basic missile, 14ft 9in; body diameter, 13.5in; span of wings, 47in; firing weight, without boost, 1,100 lb; maximum slant range, about 20 miles.



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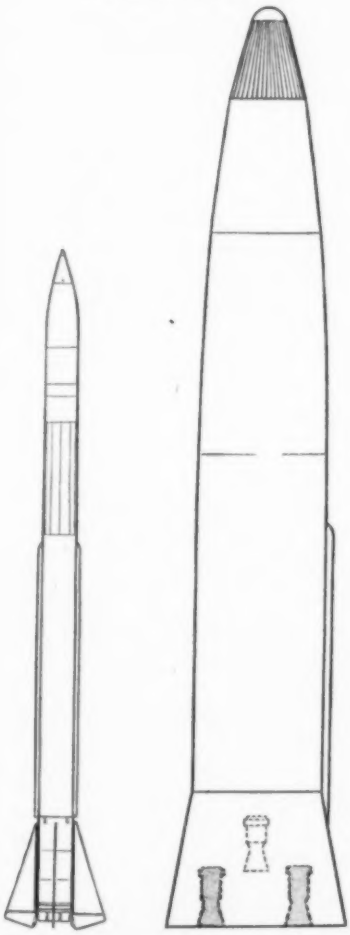
## Missiles 1957 . . .

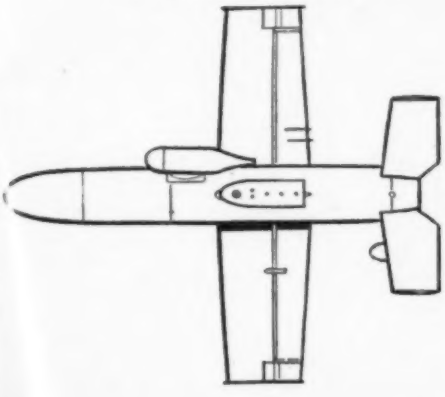
***(U.S.A.—continued)***



**Firestone Corporal SSM-A-17** (Above, left) Surface-to-surface. Liquid-propellant sustainer motor. Overall height, approximately 41ft; body diameter, 30in; fin span, 84in; launching weight, 12,000 lb; burn-out speed, Mach 3; maximum range, 50 miles.

**Convair Atlas SM-65** (Above, right) Surface-to-surface. Single airframe with liquid-propellant sustainer and flared base-skirt with two liquid-propellant boost motors; all chambers are fired on the ground and all have gimbal mountings. Height, approximately 80ft; body diameter, about 108in (114in over flare); launching weight, more than 195,000 lb; warhead speed, Mach 15; design range, 5,500 miles.

**Utica-Bend Dart SSM-A-23** Surface-to-surface. Solid (smokeless) sustainer motor. Length, approximately 5ft; wing span, 50in; fin span, 36in; firing weight, about 250 lb; cruising speed, more than 900 ft/sec; range, up to 5,000 yd.



motor, subsonic cruise propulsion being provided by a turbojet.

Second of the major developments is the TM-61B, which has now been evolved into the TM-76 described at the end of this account. Most of the Matadors in current service are of the TM-61C variety, which incorporate additional fuselage bays providing tankage for "substantially longer range," which can be utilized as a result of a new and much improved guidance system. The original "A" model was guided solely by the MSQ-series of command radar guidance, introduced to control manned-aircraft operations in Korea. MSQ requires a network of ground radars to keep the missile continuously in view, and it can thus provide positive control only as far as the line-of-sight limits of the last ground station. Incorporated in TM-61C is a second system, known as "Shanicle," which lays down a long-range hyperbolic grid (like Gee), the Matador being pre-programmed to follow a required signal pattern. Unlike the MSQ system, Shanicle can handle numerous missiles simultaneously. It has also been reported that the "Achiever" radio-inertial system developed by A.C. Spark Plug Division of General Motors has been incorporated in certain "C" Matadors.

A complete TM-61C is priced at rather more than $60,000. This weapon has been phased-in as a replacement for the earlier "A" Matador since April of this year, and it is widely used throughout the U.S.A.F., particularly in overseas units. One of the most important of these units is the 701st Tactical Missile Wing, which comprises the 585, 586 and 587 Tactical Missile Groups based in Western Germany at Bitburg, Hahn and Sembach. Once per year each squadron is deployed to Wheelus A.F.B., Tripoli, for firing trials in the Libyan desert. Each launcher and crew get a chance to fire one round on this range, so that the wing as a whole fires 36 rounds per year. This is backed-up by hundreds of simulated firings, in which T-33 aircraft fitted with Matador guidance practise the procedures of warhead arming, pre-dumping and simulated dumping in response to non-verbal signals, both visual and oral, from the ground controllers using the MSQ system.

Still more advanced and effective is the largely redesigned TM-76 Matador in which increased gross weight is matched with a smaller wing of reduced span, giving a considerable advance in all-round performance. Most important is the fact that the TM-76 operates independently of ground guidance, giving greater accuracy, much higher resistance to countermeasures and bad weather and improved base flexibility. The guidance system is the Goodyear Atran, which is basically a Doppler radar but also contains celestial and/or inertial elements. In February, Goodyear received a $1,279,496 contract to manufacture this system and a separate $1.1m was awarded in September for flight-testing. Thiokol supply the boost motor, which is manufactured by their Utah Division under a $709,758 contract placed in May. The Hallamore Division of Siegler have a $1.5m contract for miniaturized autopilot magnetic amplifiers, and Firestone are developing and testing TM-76 systems at their laboratories in Monterey.

Announcement of the first test flight by the new Matador was made in March last year, when it was designated TM-61B. Development was centred at Holloman A.F.B., and a complete integrated system was evolved incorporating the launcher, prime mover, test gear and ground-handling equipment. The TM-76 system includes a remarkable vehicle which takes the place of two separate prime movers in the earlier Matador system. The weapon itself is mounted on a "Translauncher" made by Goodyear, which is towed by a "Terracruzer" made by the Four Wheel Drive Auto Company, running on 12 balloon tyres which can be automatically inflated or deflated to suit the terrain. Ground transport is further facilitated by the fact that the TM-76 has folding wings.

Like earlier Matadors the TM-76 can carry a conventional or nuclear warhead. Production began a few weeks ago, and the first units are scheduled to convert to the TM-76 early next year. A particularly valuable feature is that a proportion of the TM-76 production weapons are being equipped with a parachute system and inflatable landing air-bags, so that user squadrons and research programmes can make far more intensive use of the missile, each round being recovered, serviced and used again.

**Navaho** Under this name North American Aviation worked under contract to the U.S. Air Force for almost ten years on the ultimate form of aerodynamic cruise-type, air-breathing weapon. As the years went by the missile got larger and more ambitious, and the scale of the operations is revealed by the fact that the overall programme cost $690m. Finally it became clear that the production weapon would be sandwiched between the subsonic Snark and the ballistic ICBM, and the whole development was cancelled three months ago—undoubtedly the biggest weapon-programme ever stopped at the stroke of a pen.

When they felt fairly sure of their ground, North American built thirteen flight-test vehicles to prove the aerodynamics and flight-control system. Designated X-10, these were impressive delta-winged devices, with a canard fore-plane and twin afterburning turbojet engines—initially Westinghouse J40s and later Pratt and Whitney J57s. Operating from Edwards A.F.B. from 1952 onwards, the X-10s flew faster than any previous turbojet-propelled vehicle, establishing level speeds between M = 2.1 and 2.3. In spite of their flashing performance they were equipped with landing gear and a braking parachute, and were landed "dead stick" at about 250 m.p.h. The first X-10 flew eight times and is now in the U.S.A.F. museum.

Progressive improvements in configuration with the X-10s were carried across to the next stage, bearing the company number G-26 and the U.S.A.F. designation XSM-64. With this vehicle a switch was made to ramjet propulsion. Take off was effected vertically, the basic G-26 being attached by pylons to a large rocket boost package comprising two 135,000-lb barrels mounted at the rear end of a streamlined tank for liquid oxygen and kerosine. Twelve XSM-64s were manufactured, and the first was launched just a year ago.

For many months the XSM-64 flight-test programme was dogged by misfortune. The first flight aborted at 9,000ft following the failure of a rate-gyro. The second, fired in March, carried off part of its launcher; this imposed unscheduled stresses until air loads finally tore the offending portion away, but boost separation took place correctly and the flight was only terminated by loss of thrust when the piece of launcher finally departed. In the same month the third round was fired, and a "wild" signal from within the missile cut the boost motor after 25 seconds and the missile and boost fell into the Atlantic. On the fourth firing the boost unit kept burning for 42 seconds but the ramjets still did not ignite, even though the maximum speed reached was Mach 1.6. Not until August 12 was a successful mission accomplished and on this occasion the limits reached were a speed greater than Mach 3, an altitude greater than 75,000ft and a horizontal distance of 350 miles (possibly the ramjet tankage was only partly filled). Instead of television, North American employed colour film in six airborne cameras recovered at the end of the mission.

The final weapon has never been fired. Bearing the company number G-28 and the U.S.A.F. designation SM-64A, it forms part of Weapon System 104 and marks the end of an epoch of missiles and piloted aeroplanes which fly to their target through the atmosphere at an approximately constant altitude. The SM-64A would have had a body as big as a B-47, fabricated from a wide variety of advanced materials including titanium alloys and bonded metal honeycombs. It was while working on this weapon system that North American evolved the process of chemical (etch) milling in 1953.

Like the G-26, the ultimate Navaho would have been launched vertically while riding pick-a-back on a huge boost package developed by the company's Rocketdyne Division. The final boost design specified a single chamber of 400,000 lb thrust, but those actually constructed were equipped with three chambers, each of 135,000 lb thrust, supplied with alcohol and liquid oxygen for 45 seconds in order to reach the ramjet ignition speed of more than Mach 1.8. The ramjets themselves were of the magnificent RJ47 variety developed by Curtiss-Wright and fabricated by the T. R. Finn Company. Each unit had a diameter of 48in and

# Missiles 1957 . . .

## (*U.S.A.—continued*)

a thrust of more than 40,000 lb. The method of ignition was remarkable. The boost package was intended to lift the whole vehicle vertically to 100,000ft, whereupon the canard fore-plane would be put fully down to push the assemblage over into a dive; the ramjet ignition system would then operate during the high-speed dive to the cruising height of 80,000ft at an ambient temperature of 600 deg F.

After boost-separation, the missile would then cruise at about this altitude to its distant target; and, although larger and slower than the re-entry part of a ballistic weapon, promised to have better warhead accuracy and to be nearer its target before coming into radar view (owing to its much lower cruising altitude). Another advantage of the winged weapon is that it can take evasive action, and the WS-104 system was certainly intended to be able to detect and avoid defending missiles. The guidance system was assigned to N.A.A.'s Autonetics Division. They evolved a pure inertial system, which was flight-tested on X-10s and was also operated at 90,000ft attached to helium balloons.

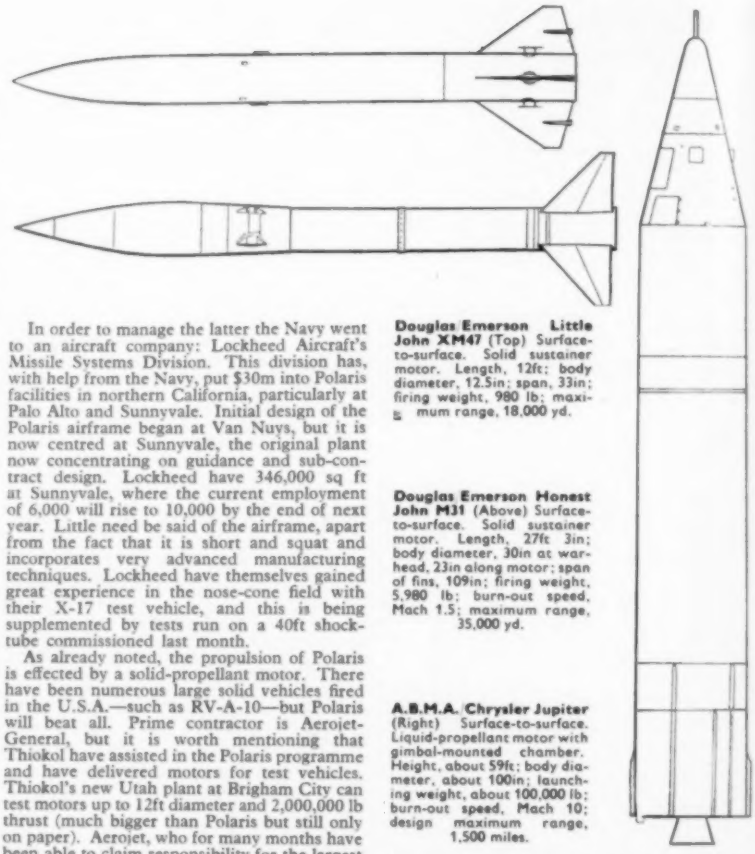
North American's three Navaho divisions (Missile Development, Autonetics and Rocketdyne) received the lion's share of the immense sum of $690m expended on the programme, although they were supported by 2,680 subcontractors. Undoubtedly the Department of Defense are correct in their contention that "had we cut it out last January, when we should have, we probably would have spent $100m less." Nevertheless, the money has largely not been wasted, and North American recently pointed out that the programme generated "advanced developments of rocket-engine power and guidance systems which are applicable to the ballistic missile programme." A general research programme is still taking place at Patrick in the firing of five remaining G-26 vehicles without undercarriage. Two of these recently flew some 500 miles, against a goal of 1,200/1,500 miles.

**Polaris** In the early stages of the Jupiter IRBM (intermediate-range ballistic missile) programme of the U.S. Army it was considered possible to produce, as an offshoot with only detail differences, a U.S. Navy version tailored to meet the demands imposed by shipboard handling. As soon as the Navy really looked into the question it became clear that their optimum weapon was of a quite different nature; an uneasy period of "marriage" followed, terminated by "divorce" on December 1, 1956.

From that date the Navy have planned intensively for the Fleet Ballistic Missile System, known as FBMS. It is by far the greatest single weapon system yet attempted by any Navy, and its implications are widespread; it gives promise of being one of the most potent offensive devices in the world. The name of the missile itself is Polaris.

Responsible for the overall direction of the FBMS is the Special Projects Office of the Bureau of Ordnance. The director of this office, Rear-Adm. William Raborn, Jr., stated that the Defense Department's famous roles-and-missions directive (which gave all land-based IRBMs to the Air Force) "meant concentration on a new, smaller, solid-propellant missile . . . . in lieu of the liquid-powered Jupiter . . . . which from the standpoint of naval striking power will provide a cheaper, safer and better weapon. It will save about $500m over the joint Army/Navy program; it will provide a production missile in limited quantities, a nuclear-powered guided-missile submarine and necessary supporting effort."

Lack of money enforced upon the Navy a conservative approach with the vast FBMS, and it has so far been taken in easy stages. Research and development contracts started to run for only about one month beyond the Fiscal Year in which they began (i.e., to the end of July 1957) and have since been extended piecemeal. Moreover a calculated risk has been taken in not providing full-scale support programmes on certain major components. But work began at the beginning of this year in several fields, particularly upon the problems of shipboard storage and check-out, underwater readying and firing, precise ship navigation, and the missile itself.



**Douglas Emerson Little John XM47** (Top) Surface-to-surface. Solid sustainer motor. Length, 12ft; body diameter, 12.5in; span, 33in; firing weight, 980 lb; maximum range, 18,000 yd.

**Douglas Emerson Honest John M31** (Above) Surface-to-surface. Solid sustainer motor. Length, 27ft 3in; body diameter, 30in at warhead, 23in along motor; span of fins, 109in; firing weight, 5,980 lb; burn-out speed, Mach 1.5; maximum range, 35,000 yd.

**A.B.M.A. Chrysler Jupiter** (Right) Surface-to-surface. Liquid-propellant motor with gimbal-mounted chamber. Height, about 59ft; body diameter, about 100in; launching weight, about 100,000 lb; burn-out speed, Mach 10; design maximum range, 1,500 miles.

In order to manage the latter the Navy went to an aircraft company: Lockheed Aircraft's Missile Systems Division. This division has, with help from the Navy, put $30m into Polaris facilities in northern California, particularly at Palo Alto and Sunnyvale. Initial design of the Polaris airframe began at Van Nuys, but it is now centred at Sunnyvale, the original plant now concentrating on guidance and sub-contract design. Lockheed have 346,000 sq ft at Sunnyvale, where the current employment of 6,000 will rise to 10,000 by the end of next year. Little need be said of the airframe, apart from the fact that it is short and squat and incorporates very advanced manufacturing techniques. Lockheed have themselves gained great experience in the nose-cone field with their X-17 test vehicle, and this is being supplemented by tests run on a 40ft shock-tube commissioned last month.

As already noted, the propulsion of Polaris is effected by a solid-propellant motor. There have been numerous large solid vehicles fired in the U.S.A.—such as RV-A-10—but Polaris will beat all. Prime contractor is Aerojet-General, but it is worth mentioning that Thiokol have assisted in the Polaris programme and have delivered motors for test vehicles. Thiokol's new Utah plant at Brigham City can test motors up to 12ft diameter and 2,000,000 lb thrust (much bigger than Polaris but still only on paper). Aerojet, who for many months have been able to claim responsibility for the largest liquid-propellant motor known, announced in May the successful static testing at Sacramento of "the largest solid-propellant rocket ever built in the U.S." It was the Polaris motor, which is now in production for the Navy Bureau of Ordnance.

Although fundamentally "simple" like all solid motors, the Polaris propulsion system does its best to become complex. The mighty charge of plasticizer and oxidant weighs approximately 20,000 lb, and (externally) is in the form of a cylinder, more than 4ft in diameter and from 25 to 30ft in length. Everything possible has been done to minimize length (to alleviate handling problems in a submarine) and the burning gases escape from a high-pressure plenum chamber through four propelling nozzles (which can be canted to impart initial spin for stabilization). The appearance of the system has been colourfully described as "an octopus with the bends." The charge is not integral with the airframe, and several have been statically fired from a single Polaris-type body on a test-stand at Sacramento. One most important factor is that, with the stable solid-grain propellant, the cut-off is "ten times as accurate" as with most liquid motors.

Few details of the guidance system of Polaris may be revealed, but it clearly is either radio inertial or truly inertial. Overall responsibility for guidance—and for the guidance of the launching vessel—is vested in the Massachusetts Institute of Technology, but most of the manufacture is being done by General Electric, the prime contractor. The latter company are also prime contractor for the shipboard fire-control of the weapon, which is required to explode the warhead (unofficially stated to weigh over 1,000 lb). A complete Polaris inertial guidance package was tested on the SNORT track at China Lake in the summer of this year.

It is now appropriate to discuss the FBMS as a whole. Recently Rear-Adm. H. G. Rickover, BuShips asst. chief for nuclear propulsion, announced that the closest approach now foreseeable to the ideal mobile platform for Polaris is the nuclear-powered submarine. "Armed with this," he said, "the N.P.S. will become an underwater satellite. It will be large enough to store, maintain and fire IRBMs and it will be able to move anywhere at any time, completely submerged." He went on to suggest that, in terms of deterrent value per dollar the FBMS would compete "more than favourably" with land-based systems. One advantage of the nuclear vessel is, of course, its absence of fuel tankage, making room for the bulky Polaris.

One of the most critical research areas of FBMS concerns the navigation of the Polaris carrier. Before a distant target can be hit by the missile its launchers must know—accurately—from where it is being fired. The problem is accentuated by the fact that the N.P.S. will move in three dimensions at quite high speeds (perhaps 50 knots), may be one thousand miles from land and may stay submerged for many weeks at a time. The answer is to be found in SINS (ship's inertial navigation system), developed principally by the Sperry Gyroscope Co. Dr. Draper, of M.I.T., has been instrumental in evolving the system, and Sperry have turned it into hardware and proved its accuracy to the satisfaction of the Navy. SINS can operate month-in, month-out with no checks from any known point on the earth's surface. It has been evaluated successfully on EAG-153 *Compass Island*, which has the full FBMS navigating and stabilizing gear, no error greater than one-quarter mile having been recorded. A second converted merchant ship, EAG-154, will soon assist in this work. To a lesser extent the FBMS is intended to include firings from surface craft, and the navigation system for these vessels will probably be related to the Sperry Cytac (which also has airborne applications).

Numerous rig tests have solved most of the problems of underwater launchings, and the Navy have expressed themselves "confident that Polaris can be fired from a submerged submarine." Recently a $10m contract was placed with Westinghouse for experimental seagoing handling and launching systems for Polaris, intended to lead to the definitive submarine system. The contract also covers various FBMS electrical and mechanical systems for submarines and surface craft. Late in

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# Missiles 1957 . . .

## (*U.S.A.—continued*)

October further tests were held to explore the precise effects of ocean currents on the missile before the latter reaches the surface. Mechanical stowage and firing problems are being tackled with a ship-motion simulator, erected in the desert by Raymond Loewy, the hydraulic-press firm. The strike of the Polaris nose-cone during firing trials will probably be pin-pointed by the SOFAR bomb, with a hydrostatic trigger, which will enable the impact-position to be fixed by cross-triangulation.

First of the new generation of N.P.S. vessels are the SSN-588, now well advanced at Mare Island Navy Yard, and the SSN-591, both of which are far larger than previous submersible craft. From FY58 money the Navy allocated $68m for the "Polaris and related equipment" (not the whole FBMS), of which $15m was requested for new support facilities. Lockheed have turned over 240 acres in the Santa Cruz mountains for Polaris R. and D., and major expansions of Polaris work are taking place at Patrick A.F.B., Aerojet-General at Sacramento, and the BuOrd laboratories at White Oak, Maryland. Funding was tripled six weeks ago, and, although no total bill can be quoted, Lockheed Aircraft announced that the contract for $62.1m placed with them in September brought the total received for Polaris operations by the Missile Systems Division to $82.6m.

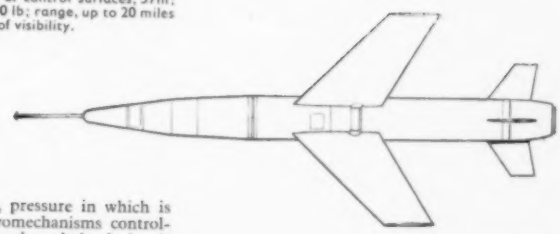
These are trivial sums in comparison with other weapon systems of comparable magnitude. The Navy once stated that they hoped to fire "a representative configuration" of Polaris in 1959, and early this year it was announced that the FBMS would "enter operational service in five years." Senator Jackson, who keeps a close eye on weapon systems, said in the summer of this year that Polaris was following a protracted schedule. He went on: "I believe we may be neglecting one ballistic-missile system which could give us a quantum jump upward in our missile deterrent power." Admiral Raborn announced an acceleration "to bring it into the front-line missile arsenal as rapidly as possible" almost the next day.

**Redeye** This appropriate name identifies a small and simple infantry weapon which is being developed for the U.S. Army by Convair at Pomona (where that company mass-produces Terrier). Guided by a simple infra-red system, the missile is intended for operations against armoured vehicles and sundry other targets, including, so it is reported, low-flying aircraft.

**Redstone** Easily the largest missile actually in service anywhere outside the Soviet Union, Redstone is (excluding Jupiter) the *magnum opus* of the Army Ballistic Missile Agency, at the arsenal from which the missile takes its name. Basically it is a straightforward ballistic device. The pointed nose and fore-body, containing a megaton-yield warhead, is guided by small control surfaces after it has separated from the main body, which is a wrapped-aluminium cylinder filled with propellants fed to a single Rocketdyne chamber. The powerplant and tanks form a section 34ft in length, 5ft more than the control-system/warhead portion. Unlike the later ballistic weapons, the motor chamber is fixed, control being achieved in "V-2" fashion with external low-speed control surfaces and refractory plastic vanes operating in the jet from the motor.

There are four main sections, joined together by an average of 20 precision-fitted peripheral bolts: the warhead, made by Honeywell's Ordnance division; the guidance, by Ford Instrument division of Sperry-Rand, of the inertial air-bearing type, with a special-purpose computer; tanks for alcohol, liquid oxygen and a steam source to drive the turbopumps; and the big rocket chamber, pressure in which is held constant by a Servomechanisms controller. In all its essentials the whole device is thus an improved V-2, and one could comment that it is a bit of a misfit in having limited range for so large a yield, and is nowhere near such good value for money as Jupiter. Production rounds are manufactured by the Chrysler Corpn., in the former Navy plant at Warren, near Detroit. Extensive tooling and widespread optical jigging have ensured complete interchangeability and repeatability of performance. After assembly, each round is "flight tested" statically, disassembled and packaged for shipment to a user battalion. Chrysler have 1,675 sub-contractors in Redstone production.

**Martin Lacrosse SSM-A-12** Surface-to-surface. Solid sustainer motor. Length, 20ft; body diameter, 20.5in; span of wings, 108in; span of control surfaces, 57in; launching weight, over 2,500 lb; range, up to 20 miles irrespective of visibility.



Most of the early production rounds were subjected to a complete weapon-system evaluation at Redstone to double-check the inspection procedures at Detroit. Chrysler now conduct an in-plant inspection which clears weapons direct to the troops. The first experimental firing was in May 1953. Exactly three years later the 40th Field Artillery Missile Group (Heavy) started training at Redstone arsenal, concurrently putting the whole system through what is termed the "weaponization" stage. Also at Redstone is the 630th Ordnance Company, providing service support. The first operational battalion was the 217th F.A.M.B., comprising 600 men organized into two batteries each with one launcher. The U.S. Navy Dahlgren computation laboratory worked out the battalion firing tables. Full details of the method of employment of Redstone were given in our 1956 review, and on p. 883 is a photograph of a weapon being assembled in the field.

**Regulus** *Regulus 1* One of the simplest and cheapest turbojet aircraft of its size ever built, Regulus 1 was planned as a subsonic, cruise-type bombardment weapon capable of being carried by a submarine. In 1947 the U.S. Navy placed a development contract with Chance Vought Aircraft (then a division of United Aircraft), and the first successful flight took place in 1951. The basic vehicle has a swept, mid-mounted wing and vertical tail and is devoid of a horizontal tail. Launching is effected with two Aerojet-General solid boost motors, and cruise propulsion is provided by a centrifugal turbojet fed from a pitot-type nose intake. The airframe incorporates much light-alloy/balsa sandwich, and the wings, each of which is arranged to fold inwards for ship-board stowage, incorporate large precision-cast magnesium panels.

From the outset, the development prototypes have been fitted with retractable landing gear and a braking parachute, and they have each flown an average of six missions. Some Regulus 1 development vehicles have flown ten times (the record is 16) and the total of approximately 1,000 flights so far conducted includes many hundreds of successful recoveries. Many of the recoverable training missiles have been flown with drone-type command guidance, but operational Regulus 1 missiles are controlled by Fairchild SPQ-2 shipboard radar, used in conjunction with an autopilot and with the possibility of allegedly active homing for the terminal phase.

Regulus 1 went on active fleet service in 1955 and has since been operated from submarines, aircraft carriers, cruisers and other surface vessels, in addition to a number of land-bases. It can carry an atomic warhead and at present represents the greatest "punch" currently available to a naval commander anywhere. Two of the submarines on active service with Regulus are *Barbero* and *Tunny*, and six months ago Firestone were awarded a contract to devise a new submarine launching system for this missile. Nevertheless, it is certain that Regulus 1 will be phased out of production as soon as its successor is operational, and last August the output from Dallas was cut back to "a bare sustaining level."

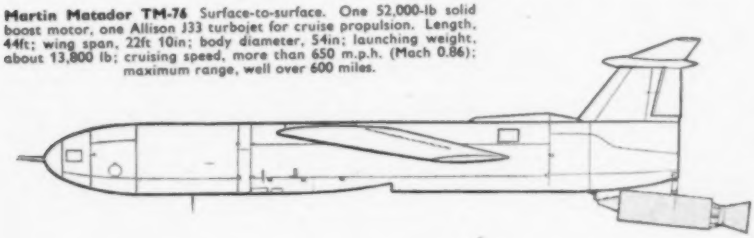
*Regulus 2* So great is the advance represented by this missile over Regulus 1 that it would have been better to have renamed it entirely. Like Regulus 1 (SSM-N-8), the Regulus 2 (SSM-N-9) is a cruise-type weapon boosted by solid-propellant rockets and powered by a turbojet. It is likewise devoid of a horizontal tail, but the pitching moments in the supersonic weapon are such that it has trailing-edge elevons and a fixed canard foreplane to increase stability. The fineness ratio has been greatly increased, and a comparison with the U.S.A.F. Snark shows that the naval planners have required Regulus 2 to have extreme performance at the expense of range.

Most of the flying so far conducted has been done with development vehicles powered by Curtiss-Wright J65 (Sapphire) engines of 7,800 lb thrust, and provided with retractable landing gear and a braking parachute. Although the sharp-edged supersonic wing has very poor low-speed characteristics, these vehicles have been successfully recovered, landing at more than 250 kt at full power with both elevons fully down. The first eight prototypes have averaged more than four flights apiece, and land-based testing is virtually completed. The performance of SSM-N-9 at Edwards A.F.B. is described as "beyond expectations," but it was marred by a single crash in June following the failure of command guidance.

Recently the first Regulus 2 was flown with the production engine, which is a special version of the constant-speed General Electric J79 with afterburner. The great increase in thrust from this engine provides a cruising speed well in excess of Mach 1, and the engine is fed from an inclined-shock ventral intake formed from a 150-lb magnesium casting with 0.24in walls and a lip radius of 0.015in. Boundary layer is bled off above the intake and dumped overboard to form a fillet beneath the wing trailing edges. Like the Regulus 1, a notable feature of the airframe is the use of large single sheets to form wing skins. Reynolds Aluminum supply 2024 and 7075 plate, measuring 60in × 180in and tapered from 0.25in at the root to 0.032in outboard. Control is effected solely by the elevons and rudder, the autopilot being the same Sperry unit as is used in Regulus 1 operating in conjunction with Stavid radio command. The production weapon will have a choice of at least two guidance systems, including a Sperry inertial guidance and another system developed at Milwaukee by A.C. Spark Plug (possibly resembling the A.C. Matador system).

Production SSM-N-9s will not, of course, have landing gear, and when under-wing tanks are fitted their range will reach 1,000 miles. They will have megaton ability, and are likely to prove so potent that "a new generation of submarines" is being designed to carry them. The first ships designed to operate with a Regulus 2 weapon system will be those already operating with Regulus 1, since the conversion is a minor one. The submarines *Grayback*, *Growler* and *Firestone* are being converted to

**Martin Matador TM-76** Surface-to-surface. One 52,000-lb solid boost motor, one Allison J33 turbojet for cruise propulsion. Length, 44ft; wing span, 22ft 10in; body diameter, 54in; launching weight, about 13,800 lb; cruising speed, more than 650 m.p.h. (Mach 0.86); maximum range, well over 600 miles.



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## Missiles 1957 . . .

*(U.S.A.—continued)*

carry the new weapon, and *Halibut* is a nuclear-propelled submarine which is being built "from the keel up" to operate with Regulus 2. The first rocket-boosted launching of a production-type Regulus took place on November 13, and the weapon is going into production at Dallas and should be operational next year.

**Sergeant** Owing to its early conception it is only natural that Corporal should be far too large and complex for the task which it performs. Sergeant, which will replace Corporal, is a moden weapon carrying the same payload for at least an equal range with far less complexity, implying lower cost, better field performance and greater availability. Like the earlier weapon, the basic development was conducted at the J.P.L. of the California Institute of Technology. Numerous development rounds have been fired with singular success, and the weapon is also profiting from the fact that its propulsion system has been extensively employed in the Lockheed X-17 re-entry research vehicle.

J.P.L. announced that "the latest techniques in guidance, airframe design and rocket propulsion are being applied to the development of this rugged weapon, which is capable of operating in any area." Propulsion is provided by a high-impulse solid motor developed by Thiokol at Redstone and produced at the new Utah Division. Motor thrust is much greater than that of Corporal and the filling is a cast polysulphide plastic-base composition burning for some 30 sec. The warhead is a product of Honeywell's Ordnance Division and the complete weapons system is going into production at Sperry-Rand's Utah Engineering Laboratories at Salt Lake City.

*Artist's impression of a North American G-28 SM-64A Navaho. Weighing one hundred tons, the weapon climbs vertically, riding on a 405,000 lb-thrust rocket-boost unit (see text).*

**Snark** Between 1943 and 1948 Northrop Aircraft investigated the widespread aerodynamic and structural problems of tailless aircraft. This configuration was finally adopted for a pilotless bomber with the U.S.A.F. designation XB-62, and a number of scale models were made for tunnel and free-flight investigations. This history was fully reported in our issue of March 16, 1956, and also in our 1956 missile review. Development vehicles were flying in 1951 and representative configurations of the ultimate outcome, the SM-62 Snark missile, were first launched in 1954 powered by an Allison J71 turbojet. Numerous XSM-62 development vehicles were fired from Patrick A.F.B., a number having under the body tandem oleo legs fitted with skids supplemented by small skids at the wing tips, so that, with a braking parachute, they could be recovered. Thirteen such vehicles were lost during early testing as a result of various malfunctions, but the solid endeavour put in at this period has now resulted in a weapon system of exemplary reliability. In its fully developed form the SM-62 Snark is a shapely aircraft-type weapon with a high-mounted, swept wing fitted with elevons. In conjunction with the swept fin and tiny rudder, these surfaces serve all the stability and control functions; there is no horizontal tail.

As at present conceived, the SM-62 is fired from a zero-length launcher under the thrust of two Aerojet-General solid boost motors. It then climbs away on the power of a constant-speed Pratt and Whitney J57 turbojet up to an altitude of approximately 50,000ft, thereafter following a cruise-climb path at Mach 0.94 for a range of approximately 5,000 miles, eventually reaching a height of some 55,000ft. Drop tanks are carried under the wings and jettisoned during the journey. Extensive aerodynamic investigations have resulted in a configuration which, although it flies at what may seem an excessive angle of attack, has the optimum lift/drag ratio and a specific range of better than one mile per gallon.

Noteworthy parts of the structure include the upper and lower wing skins, for which single slabs of cast magnesium alloy were evolved, and the numerous areas fabricated from aluminium honeycombs. The powerplant group forms a compact package at the rear, the remainder of the lengthy fuselage being occupied by kerosine tanks, guidance and control systems and the megaton-yield warhead. The latter is accommodated in the nose, where it is released by Bohanan force-ejection devices in the final supersonic dive on to the target. Beneath the nose is the large radome, by Zenith Plastics, which is presumably associated with countermeasures systems. The guidance, which is also a product of Northrop Aircraft, weighs approximately 1,000 lb and is an unusual and interesting hybrid device combining celestial (star-tracking) and inertial functions. Northrop originally suffered greatly from the problems of launching acceleration and in-flight vibration, but these were cured by a "reliability program" applied to the guidance system.

During the past two years, a large number of development XSM-62s and pre-production SM-62s have been tested from Patrick A.F.B. Some of the former have been flown on out-and-return flights and landed back at Patrick, but one weapon achieved notoriety in December last year when an XSM vehicle under command guidance from Patrick failed to make a required turn and was written-off as "lost in the jungle of E. Brazil." In April of this year, when a complete airframe had just completed structural testing at W.A.D.C., an order was placed for 50 additional development SM-62s, and by June the total Northrop employment on the weapon reached 7,800. The big question of whether or not the weapon would be put into the U.S.A.F. inventory was answered the following month, when a production order for $73m was placed, with delivery to Strategic Air Command due to start in the second half of FY58, i.e., between January and June next year. The former assistant defence secretary, Ruben B. Robinson, said: "it is possible to activate Snark squadrons by the end of calendar 1958. . . . It has its disadvantages of being subsonic, but will probably have quite an accurate guidance system as is now visualized and a very good circular-error probability." This seems to have been borne out by a development flight on October 30 when a Snark conducted a complete simulated mission in the face of various types of interception and countermeasures, and struck a target at least 4,000 miles from Patrick "with unprecedented accuracy." This was hailed as "the first true demonstration of intercontinental nuclear capability in the world."

The complete SM-62 weapon system can be transported in a C-124, including the launching vehicle which is towed by a tractor and carries the weapon on zero-length pivoting arms (originally a 29ft elevating rail was employed). The three launchers assigned to an S.A.C. squadron can be operated from any reasonably flat site and can theoretically conduct twenty firings in a 24-hr period. Last month contractors were assigned to prepare facilities for the first operational sites on the Atlantic seaboard. Northrop have also prepared studies for an RM-62 reconnaissance Snark for damage-assessment missions after ICBM strikes.

**Thor** When the Wilson Memorandum of November 1955 gave the U.S. Air Force complete control of all weapons with a range greater than 200 miles the U.S.A.F. instituted a "crash programme" for an IRBM (intermediate-range ballistic missile), to compete with the U.S. Army's Jupiter. From the outset this programme has been fraught with politics, and the prime contractor—Douglas Aircraft—has had the unenviable task of rushing through critical decisions, accelerating firing trials in the glare of public limelight and producing a reliable weapon at the earliest moment, knowing all the time that the final weapon might be not their own but the Jupiter, or a hybrid "Thorpiter" drawing upon both programmes.

There is no parallel case of a major weapon system being developed in such a critical climate, or with the knowledge that it may have to be "married" with a quite different system—causing frustration, rather than acting as a spur to greater efforts.

Be that as it may, Douglas and their subcontractors have performed a series of miracles in producing SM-75 Thor in exactly one year. The overall weapon system, WS-315A, draws heavily upon the Atlas ICBM; it uses for propulsion a unit resembling an Atlas boost motor, it has the Atlas nose cone and its guidance involves equipment already largely developed for either Atlas or Titan. In contrast to the more conservative, and less-wealthy, U.S. Army, the Air Force have gone into their IRBM programme head-long, on a maximum-risk basis. Douglas have designed Thor as a production weapon from the outset, and, long before a complete missile had been assembled, development XSM-75s were being produced on an assembly line using production tooling. Altogether the programme has followed Cook/Craigie lines, in which a widespread and intensive programme of testing has been used to ensure that each development missile is slightly nearer to the definitive operational weapon than was its immediate predecessor.

By so doing, the U.S.A.F. have made it possible for Douglas to be in a position to deliver in bulk at a relatively early date; and they have not been reluctant to use the fact that Thor is built on an "assembly line" in their bitter political battle with the team developing the Army Jupiter. It is only natural that such a policy should have led to relatively unsatisfactory progress in the early stages of flight trials, and the Army in their turn have seized on Thor's "series of disasters" as useful ammunition for their own cause.

Thor is a single-stage missile, with a lightweight airframe drawing upon the experience of such companies as Convair, North American and Martin. At the top is the nose cone, almost a facsimile of that evolved for the SM-65 Atlas. The nose-cone contract held by General Electric's MOSD amounts to $158m, and of this about $40m is probably ascribable to SM-75. Next comes the Sandia warhead, probably

weighing about 1,500 lb, and the third major section contains the guidance package, accessible through a large door shown in the drawing.

Prime contractor for guidance is the A.C. Spark Plug division of General Motors, who in July were awarded their definitive research and development contract, which came to $38m. The system includes an inertial platform with Minneapolis-Honeywell HIG liquid-floating gyros. As a backstop is a Western Electric system (evolved for the Titan ICBM) of the radio-inertial type. B.T.L. (Bell Telephone) ground radar is specified and Packard-Bell are also named as a major electronics contractor. Sperry-Rand supply the essential Univac computer.

The rest of the airframe consists of integral tankage for the liquid oxygen and kerosine, and although it is pressurized this is done as much to assist propellant feed as to preserve shape and structural integrity. Each tank is built up from three panels each forming a 120-deg segment of the finished section. Careful stretch-press operations give the panels curvature in two planes—the drawing shows that overall diameter changes constantly—and the inside of each skin is milled to leave a type of "waffle" pattern giving adequate stiffness. The web thickness, which is held to great accuracy, is reported to be 0.25in.

At the bottom is the gimbal-mounted Rocketdyne S-3 motor, rated at 160,000 lb thrust. This is higher than the thrust of the Atlas boost motor, but the chambers are not dissimilar. All control of the flight of Thor is obtained by varying the axis of the chamber. Surrounding the motor is a flared skirt on which are mounted four small delta fins, giving increased stability during the first few seconds of flight.

Thor thus makes a neat package of destruction; yet even the engineering skill of its creators could not save the flight-test programme from a bad start. The first XSM-75 was on the firing pad at Patrick in November 1956, twelve months from the start of design (and six months earlier than the first XSM-65, which contributed so much to its rapid design). It took two months to assemble a complete set of ground units, conduct all the checks and bring everything to a state of full serviceability. Thor No. 1 took to the air in January. It rose a distance estimated variously as "two feet" and "a matter of inches"; then contamination by foreign matter in the liquid oxygen caused a malfunction in a starting valve, resulting in an immediate loss of thrust. The XSM-75 fell just hard enough to cause structural failure, and the remaining propellants exploded.

It was not until April 23 that the Douglas engineers and their sub-contractors were able to fire the second round. This one achieved a clean launching, but shortly began to "wander" from its programmed course (this was challenged later, by a report which claimed that the Patrick tracking system was at fault) and, in order to prevent it from falling on the Florida mainland, was detonated by the range-safety officer after a flight of 38 sec. Even more galling was the fate of XSM-75 No. 3, which was scheduled for firing in June (before an expectant audience estimated at 1,200 sightseers). Four minutes before the end of the count-down, an electric circuit associated with the kerosine pressure-regulator shorted, leading to an uncontrolled fuel spillage. Two spectacular explosions followed and the weapon was engulfed in a vast fireball of kerosine, most of which had burnt when the liquid oxygen tank burst shortly afterwards.

This seems to have been enough "crash programme" for both Douglas and the Air Force, who have since followed a policy of advancing more methodically in smaller steps. No longer has the entire weapon system been made to work at each firing; instead a policy of maximum reliability and intensified static and component testing has been adopted. Douglas and the U.S.A.F. each put $3m into a Thor test-facility on 1,700 acres near Nimbus, Sacramento (adjoining the Aerojet-General "campus"), which, begun in November 1956, is now engaged in captive firing of complete weapons. By July Douglas were training Air Force personnel with SM-75 mock-ups and the flow of XSM-75 development rounds passed the one-a-month level.

On the fourth and fifth firings success still eluded the harassed team, but on September 20 the sixth XSM-75 went "all the way" at last, with a flight of 1,350 miles with excellent telemetering. The next, fired on October 4, exceeded its design figures by a substantial margin and went some 2,000 miles downrange. In that month the Defense Department pointed out that less than ten per cent of the test vehicles allocated to the IRBM (Jupiter and Thor) programmes had been fired, and called for a major acceleration. Douglas responded with a second firing in the same month (on October 23) this being the eighth round and the third consecutive success. There have been several firings since.

Engines for XSM-75s have been built at Rocketdyne's main plant at Canoga Park, Cal. Production motors are manufactured at the new $13.2m facility at Neosho, Missouri, which also produces units for Jupiter and Atlas. Employment at Neosho has already climbed to 750 and should reach double this number by next June. The first Neosho-built Thor engine carried out the test-stand "shake-down" tests early in October, and production units are now being put through regular acceptance tests. Firings at Patrick are being accelerated, and the J.C. Harper Construction Co. were recently awarded a $700,000 contract to "change the house and loading dock for WS-315A" at this establishment. Thor transporters are built by the Fruehauf Trailer Co. against a contract worth $15m.

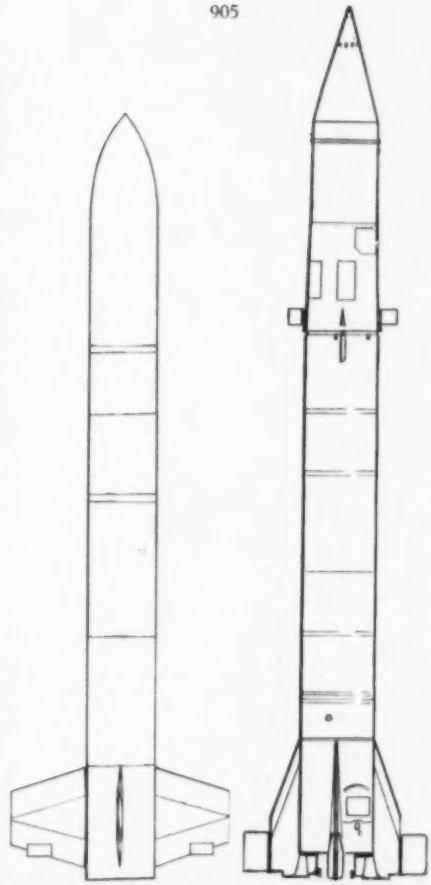
Douglas Aircraft's own major SM-75 contract so far is for $67.5m; placed in January, it covers "airframe fabrication and testing." Largest of the individual contracts is the Western Electric/B.T.L. (Whippany, N.J.) guidance contract, which, including SM-68 Titan, was finally agreed three months ago at $104,192,000. Total IRBM investment by October was $430m, of which WS-315A has absorbed about $230m. It is reported that about $130m is allocated to the programme from FY58 funds. A single production SM-75 would cost about $500,000.

As noted at the outset, the production U.S.A.F. weapon will be either Thor, or the Army Jupiter, or a hybrid "Thupiter" or "Thorpiter" (according to the ratio in which the weapons are merged). On September 13, Charles Wilson, about to retire from the position of Defense Secretary, said "the merger can be achieved without undue delay. I believe that it is possible to produce such a merged weapon in quantity in about a year." But, at his final Press conference in October, Wilson announced the temporary shelving of plans for a merger, on the advice of the Holaday-Medaris-Schriever committee. Thor has no shortage of funds, and both it and Jupiter will be developed further to see if either shows itself to be clearly superior.

Last week the Department of Defense took the momentous decision of allowing the development programmes for both Thor and Jupiter to go at least as far as the preliminary stages of production; and it was implied, but not stated definitely, that the two weapons might be procured in inventory quantities and operated alongside each other by Strategic Air Command. In the past few days additional Thor and Jupiter development vehicles have been fired; and, surprisingly, one of the latter malfunctioned owing to "technical difficulties." As is briefly noted in the description of that weapon, the nose cone of Jupiter is coated with from seven to ten layers of refractory plastic material, the underlying structure being a skeleton of titanium alloy; several of the outer layers are allowed to burn off during re-entry. Thor, on the other hand, has a slightly different type of nose cone, although part of the re-entry body is covered with special plastic laminates with a depth equal to half the probable wave-length of long-range radars, so that the reflected signal is greatly reduced in strength. Most of the Thors so far fired have been engaged in the development of airframe and propulsion, the former in particular being entirely new and somewhat of an unknown quantity in comparison with the so-called "hand-built" and relatively conventional body of Jupiter. Most of the XSM-75s have been equipped to follow a pre-programmed trajectory using an autopilot, whereas the Army weapon has now completed numerous trials with full guidance.

As a result of the Macmillan-Eisenhower talks early this year, the outcome of the Thor/Jupiter programme will be supplied not only to the U.S.A.F. Strategic Air Command but also to the United Kingdom. Nuclear warheads will not be supplied, but will be retained by U.S. forces—presumably the 7th Air Division—for allocation to the British IRBM user—presumably the Army—on Presidential authority.

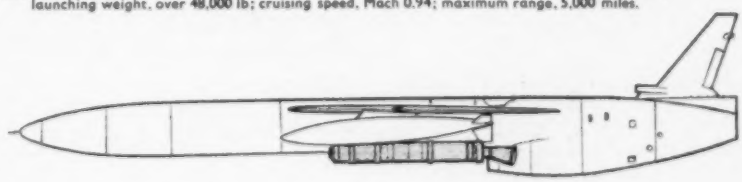
**Titan** During 1955 the U.S. Defense



**Sperry Sergeant** (Left, above) Surface-to-surface. Solid sustainer motor. Overall height, about 32ft; body diameter, 36in; fin span, about 110in. Launching weight, probably about 15,000 lb; burn-out speed, at least Mach 3; maximum range, about 50 miles.

**Chrysler Redstone XMS** (Right, above) Surface-to-surface. Liquid-propellant sustainer motor with jet-deflection by vanes. Height, excluding nose probe, 63ft; body diameter, 72in; fin span, 12ft; launching weight, about 40,000 lb; burn-out speed, Mach 5; maximum range, more than 200 miles.

**Northrop Snark SM-62** Surface-to-surface. Two 33,000 lb-thrust solid boost motors, one Pratt and Whitney J57 turbojet for cruise propulsion. Body length, excluding probe, 69ft; wing span, 42ft; launching weight, over 48,000 lb; cruising speed, Mach 0.94; maximum range, 5,000 miles.



# Missiles 1957 . . .

## (*U.S.A.—continued*)

Department agreed with the U.S. Air Force that the ICBM was the most important of all weapons, and that it was unwise to place complete reliance in one single design. Accordingly a "crash programme" was instituted for the development of a second ICBM, making the maximum practicable use of the scientific and engineering effort already undertaken for the first, while having an entirely different configuration.

Titan, as the second ICBM is known, has the Weapon System number WS-107A-2, and the missile itself is SM-68. Obviously, any parts of the system which can be shown to be superior to those in the other U.S.A.F. ballistic weapons will become widely adopted. At present SM-68 employs a host of small parts and techniques originally evolved for Atlas, as well as a wide range of ground equipment common to other systems, but the airframe and propulsion system are peculiar to Titan. Overall, the cost of the WS-107A-2 programme is estimated at 10 per cent of the expenditure required to develop a single configuration (i.e., Atlas and Titan are costing 110 per cent of the cost of either alone).

Prime contractor for Titan is The Martin Company, whose initial development contract is for the exceptional sum of $358m. It is fair to add that this contract covers design, fabrication and testing, and runs for a relatively long period. Their airframe is outstanding in several respects, in spite of the fact that the design requirements are, in general, exceptionally arduous. One of the chief factors complicating the structural problems is that SM-68 is a true two-stage missile. The first stage comprises a 10ft-diameter cylinder containing liquid oxygen and fuel and housing at its lower end the most powerful single-chamber motor in the world (outside the U.S.S.R. at least). Into the upper end of this cylinder is fitted the second stage, which is appreciably smaller. The second stage contains its own motor and tankage, as well as all the guidance, the warhead and nose cone. Only the first-stage motor is fired on the ground, the second unit being started at the point of burn-out and separation of the first stage.

As far as possible airframe weight has been minimized by employing integral tankage and thin skins. In general, however, skin gauges in the first stage are greater than those in Atlas (SM-65), since the overall missile stands much higher and the first stage has to bear all the weight of the second. Virtually all the structure of the first stage is built up from light-alloy panels 34in wide and either 140in or 280in high, according to whether they are for the fuel or oxygen tank. The material is 2014 alloy in the T4 condition (57,000 lb/sq in u.t.s.). Initially each panel is stress-relieved and machined to leave three T-section axial stiffeners (finish size $\frac{1}{4}$in web $\frac{3}{32}$ thick with a $\frac{1}{4}$in flange), after which the remaining skin is surface-milled to a thickness of 0.150in +0.003. The panels are then formed in a Hufford bi-axial stretcher to the required 60in radius, so that each becomes a 30-deg segment of the final tank. Heat-treating and ageing to T5 (64,000 u.t.s.) follows, after which each panel is chemically milled to 0.070in +0.01in and exterior pockets are sculptured leaving a final thickness between the T-stiffeners of 0.05 +0.005in (a surprisingly large tolerance). Twelve panels are then butt-welded to form a complete section.

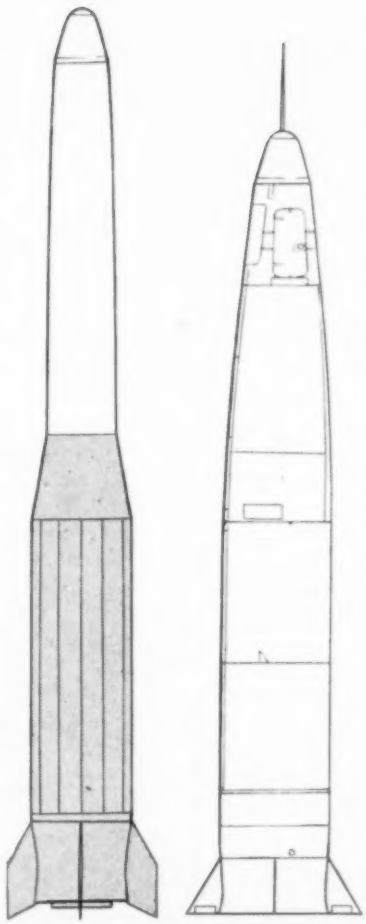
Propulsion has been entrusted to Aerojet-General, Azusa, Cal, with a main propulsion contract amounting to $55,650,000. The first-stage motor has a single gimballed chamber rated at 300,000 lb thrust; the rating of the second-stage motor is 60,000 lb. Both units run on liquid oxygen and kerosine. Titan motors are fabricated at the company's Metal Parts plant (U.S.A.F. Plant No. 70), Sacramento, which has 24 test stands each of which is used on an average once per day. It was stated last month that Titan propulsion is on schedule.

There are two possible guidance systems under development. One is the pure inertial system by the Arma division of American Bosch, Garden City, N.Y., with which is associated a "reference system," or true inertial platform, by the Minneapolis-Honeywell Regulator Co. The second system, now regarded more as a back-stop against failure of the first, is the radio-inertial system by Western Electric/Bell Telephone Laboratories, at Whippany, N.J. Their contract, which includes a similar system for the Thor (SM-75), amounts to $104,192,000. Either system is almost certain to incorporate a computer by the Remington Rand (Univac) division of Sperry-Rand, at St. Paul, Minn. A further computer is under development at Beckman's new plant at Anaheim, Cal, and ground radar for the radio-inertial system is being prepared by Bell Telephone Laboratories. All Titan electronics are designed to new, and very arduous, specifications, and are "rugged" enough to retain high reliability without antivibration mounting. A complete guidance package was subjected to acceleration and vibration tests last April, using the supersonic SNORT track at China Lake.

Prime contractor for the nose cone is Avco, at Lawrence, Mass, whose Everett, Mass, facility hold a contract for $111,308,359 for this vital component. Their large shock-tube has proved invaluable in simulating—literally duplicating—re-entry conditions in the laboratory. This is a technical "break-through" on a par with the discovery of the properties of the blunt nose itself, and it has allowed the final design of nose cone to be determined before the first SM-68 has been fired. Avco have been in production with prototype nose cones for six months. Responsibility for the warhead is vested in the Sandia Corpn., at Albuquerque.

Martin's enormous effort on Titan is progressively being concentrated at a completely new plant built for the purpose at a cost of at least $15m. The headquarters of the company's Denver division, it is some 20 miles from the city in Jefferson County, Colorado. The plant layout, which is largely unclassified (not secret), reveals that the task of mass-producing an ICBM cannot be efficiently undertaken in a former aircraft plant (and, should this ever be of interest, that the reverse is virtually impossible). Complete first and second stages of SM-68 will finish up on parallel lines and the missiles will leave the plant through a modest door at one end. They will then be taken to vertical test stands for acceptance trials. Baldwin-Lima-Hamilton are a major supplier for test stands, and the instrumentation includes 10 of the large Beckman 101 analogue computers. Transtainers (transporter-containers) for SM-68 are of novel design, with a structure of aluminium alloy. Transtainers, and much of the other ground gear are built by North American's Los Angeles division.

Several prototype SM-68s are nearly complete. Structural testing began on schedule in June and the first firing should take place early next year. Altogether the programme has been rapid and successful, reflecting the ability and experience of the contracting companies. It is surprising to note that the programme is reported to have been "stretched-out" by no less than ten months, owing to economy measures dictated at the highest level. The original schedule called for 80 inventory SM-68s to be on S.A.C. firing pads by 1961. It is significant to note that Charles Wilson, when he was Defense Secretary, said, "the one we think is best is probably further behind, implying that SM-68 may be a better weapon than the SM-65 Atlas. It should be, if starting later is a reasonable criterion.



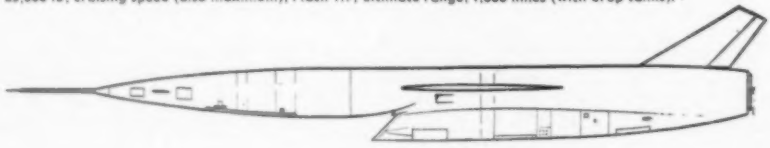
**Martin Titan SM-68** (Right) Surface-to-surface. Two separate stages, each with one liquid-propellant motor with a gimbal-mounted chamber. Overall height, about 105ft; body diameter of first stage, 120in; launching weight, about 200,000 lb; warhead speed, Mach 15; design maximum range, 5,500 miles.

**Douglas Thor SM-75** (Far right) Surface-to-surface. Liquid-propellant motor with gimbal-mounted chamber. Height, about 65ft; maximum body diameter, just over 100in; launching weight, probably just under 100,000 lb; burn-out speed, Mach 10; design maximum range, 1,500 miles.

**Triton** In order to acquire a full "spectrum" of guided weapons, the U.S. Navy sponsored the development of a long-range, supersonic, air-breathing bombardment missile falling mid-way in capability between Regulus 2 and Polaris. McDonnell Aircraft were selected as prime contractor and they evolved a fine-looking airframe 47ft long, and with a cylindrical body 57in in diameter, housing kerosine fed to a pair of large ramjets (bigger than those used in Talos). Extensive research, tunnel testing and systems development took place between 1955 and the summer of this year; in particular, a self-contained guidance system was evolved by Goodyear (incorporating Kearfott inertial-quality gyros and reported to form a unique and relatively cheap system).

The weapon would have weighed about 20,000 lb with fuel for a range of 1,500 miles, cruising at 80,000ft at Mach 3.5. Two large solid boosts were intended to launch Triton from any ship equipped to carry Regulus, and it is probable that Triton would have been a very effective weapon, particularly in its later "zip-fuel" developments. Nevertheless, the programme was cancelled two months ago, in view of the supposed imminence of the Fleet Ballistic Missile System. Total expenditure was $24m, of which McDonnell received $6.5m in one contract. Out of the 750 engineers in that company's engineering division, some 300 were assigned to Triton, but no redundancy is expected to ensue. Certain aspects of the programme, especially those concerned with guidance, are being continued.

**Chance Vought Regulus 2 SSM-N-9** Surface-to-surface. Solid-boost motors (not shown) and one General Electric J79 turbojet for cruise propulsion. Length, 57ft; span, 20ft; launching weight, 23,000 lb; cruising speed (also maximum), Mach 1.9; ultimate range, 1,000 miles (with drop tanks).



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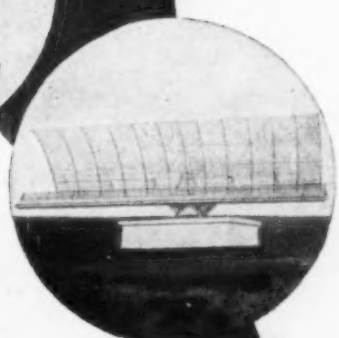

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# SERVICE AVIATION

*Royal Air Forces and Naval Aviation News*

### Honorary Royal Physician

APPOINTED Honorary Physician to the Queen, A.V-M. James Hill succeeds A.V-M. F. E. Lipscomb, who is retiring from the R.A.F.

A.V-M. Hill was last month appointed Principal Medical Officer at Home Command, after serving as P.M.O. at Technical Training Command since 1954. He joined the medical branch of the R.A.F. in 1927.

### Publicity Award

AT the Air Public Relations Association reunion in the R.A.F. Club on November 28 the C. P. Robertson Trophy, awarded annually for the most effective piece of publicity for the R.A.F., was presented to Mr. Alan Chivers of the B.B.C. Mr. Chivers was executive producer of the television programme *This is Your Royal Air Force*, first seen on May 15. The trophy was presented to him by the Secretary of State for Air, Mr. George Ward.

### Benevolent Fund Aid

FINANCIAL aid by the R.A.F. Benevolent Fund to members of the R.A.F., W.R.A.F. and their families and dependents totalled £430,970 during the first nine months of this year, an increase of approximately 6 per cent compared with the corresponding period of 1956. For London, the figure was £25,128 higher than for last year, although the number of instances in which help was given remained approximately the same—12,191 as against 12,154.

### Antarctic Christmas

THIS will certainly be a white Christmas, and perhaps a very busy one, for the four-man R.A.F. detachment with the Trans-Antarctic Expedition. Now that Dr. V. E. Fuchs and Sir Edmund Hillary are on the march to their historic meeting, the detachment's Otter and Auster have to be at continual readiness to carry stores or give assistance if required. This means that the two pilots, S/L. J. H. Lewis (commanding officer) and F/L. G. Haslop, will on Christmas Day be either flying towards the South Pole or on stand-by; and the two ground crew N.C.O.s, F/Sgt. P. B. Weston and Sgt. E. Williams (who has now spent two years continuously in the Antarctic), will be alert to see that their Otter and Auster charges are serviceable.

### R.A.F. Appointments

AMONG appointments recently announced by Air Ministry are the following:—

G/C. A. G. Douglas to H.Q., F.E.A.F., for administrative staff duties; G/C. R. F. Folley to H.Q., Coastal Command, for administrative staff duties.

W/C. A. G. Sutton to H.Q., No. 40 Group, for air staff duties (with the acting rank of group captain); W/C. S. Baker to R.A.F. Wittering, to command No. 138 Sqn.; W/C. P. Cartridge to the Joint Services Air Trooping Centre, Hendon, to command; W/C. W. H. Ingle to R.A.F. Lindholme, for administrative duties; W/C. R. E. Skelley to Air Ministry, for duty in the Department of the Chief of the Air Staff; W/C. F. O. Barrett to No. 5 F.T.S., to instruct; W/C. P. C. Cleaver to Air Ministry, for duty under the Air Member for Supply and Organization in F.E.A.F. as a member of the Asian Establishment Committee; W/C. B. G. F. Drinkwater to No. 6 F.T.S., to instruct; W/C. C. T. Nance to the R.A.F. Staff College, Andover, for directing staff duties; W/C. T. A. Whiting to R.A.F. Cottesmore, for flying duties; W/C. J. H. Woffindin to H.Q., 27 Group, for technical staff duties; W/C. W. D. Woods to H.Q., 18 Group, for technical duties as Senior Technical Staff Officer; Acting Wing Commander K. E. Hollom to H.Q., Flying Training Command, for equipment staff duties.

S/L. J. C. Archibald to Air Ministry, for duty in the Department of the Air Member for Supply and Organization (with the acting rank of wing commander); S/L. R. W. Marshall to R.A.F. Records Office, for administrative duties (with the acting rank of wing commander); S/L. G. H. Melville-Jackson to R.A.F. Tangmere, to command No. 25 Sqn. (with the acting rank of wing commander); S/L. G. J. N. Neal to Air Ministry, for duty in the Department of the Air Member for Supply and Organization (with the acting rank of wing commander); S/L. J. C. Campbell to Air Ministry, for duty in the Department of the Chief of the Air Staff (with the acting rank of wing commander); S/L. L. Cottingham to the Ministry of Supply (with the acting rank of wing commander); S/L. J. W. J. Leggett to R.A.F. Horsham St. Faith, to command No. 141 Sqn. (with the acting rank of wing commander); S/L. B. W. Parsons to R.A.F. St. Eval, to command No. 42 Sqn. (with the acting rank of wing commander).

*A.V-M. H. D. Jackman, C.B., C.B.E., whose appointment as A.O.C.-in-C. Maintenance Command was recently announced.*

### IN BRIEF

R.A.F. command, station and individual road-walking championships will be held at Henlow on January 29, 1958.

* * * * *

A total of 452 spare-time observers—371 men and 81 women—were recruited last quarter by the Royal Observer Corps.

* * * * *

Damage as a result of the fire at R.A.F. Akrotiri in Cyprus last week has been estimated at over £1m. A Venom and four Canberras were virtually destroyed.

* * * * *

Learmouth, one of the wartime airfields built for the defence of Darwin, is to be reconditioned for present-day R.A.A.F. use at a cost of £A500,000. In the extreme west of Australia, it is situated on the shore of Exmouth Gulf, south of the Monte Bello Islands.

*H.M.S. "Ark Royal" launched 36 aircraft —18 Sea Hawks, 12 Sea Venoms and six Wyverns—by steam catapult in less than twenty minutes while lying at anchor in the Firth of Forth last week. Here one of the Wyverns is on the point of departure and a second stands by to go; while a Whirlwind on plane-guard duty gives this F.A.A. portrait a markedly Westland character.*

# CORRESPONDENCE

*The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns; the names and addresses of the writers, not for publication in detail, must in all cases accompany letters.*

### In Defence of the Ministry

HAVING experienced a reasonable share of the fatuities perpetrated by this country's civil aviation Ministry, it is with reluctance that I write to suggest one instance in which this body may well be doing something that is sensible. I refer to the letter from Mr. Conry (*Flight*, November 15) in which he rebukes the Ministry for not granting a student pilot's licence to a man with only one eye. I quote: "Seeing no reason why a one-eyed pilot would be any worse than a two-eyed pilot in a modern aircraft with its built-in blind spots, we went in to bat for him. . . ."

Rubbish, Mr. Conry! You know perfectly well why a one-eyed pilot will be worse than a two-eyed pilot. And every other pilot who has ever taken a depth-perception test and a range-of-vision test knows it, too. If "your Association" is still in doubt, then why not consult the Association's medical adviser?

Whether flying in a crowded traffic-pattern or driving on a fast, open road—and in any other situation where judgment of relative speeds can be critical—I prefer the people controlling the other vehicles near me to have two eyes, Mr. Conry. And so do you, if you're not crazy.

Granted that the M.T.C.A. official's alleged first question was impertinent. Granted also that the licences already allegedly issued to one-eyed pilots indicate inconsistency. But I'll take impertinence and inconsistency rather than an increased chance of an early death in a flying accident. I'm too young to die, Mr. Conry, and when I am flying I like everybody else in the air to be as fit as possible—quite apart from the fact that they may need to be when I am flying. Call me selfish if you like.

As a matter of fact you can call me ignorant, too, because I don't really know much about your Association, other than the facts that you are hon. secretary and you have written to *Flight* a couple of times and that you don't like the M.T.C.A. Unfortunately no announcement seems to have been made of the formation, aims or activities of your Association. I have only one final question, Mr. Conry. Well?

London, S.W.8. K. TUDOR.

### Underneath the Arches

REFERRING to recent correspondence, I think that the structure that was most frequently flown under, and even looped round, was undoubtedly the aqueduct at Shoreham during the 1914-18 war.

Gulval, Penzance. E. C. D. MALONE.

### Early Catalogues

AS a follow-up to the correspondence on the first aviation catalogue, on the back cover of *Flight Fittings 1911*, the tenth catalogue of T. W. K. Clarke and Co. (established 1906) there appears a reproduction of the "first aeroplane advertisement":—

"Aeroplanes, Gliders and Hydroplanes designed and built. Apply T. W. A. Clarke, 25a Westminster Palace Gardens, Victoria St., S.W."

This advertisement was the subject of a column in the *Daily Mail* of December 3, 1906—and one suspects, therefore, the hand of Harry Harper. F. H. SMITH,

London, W.1. Librarian, the Royal Aeronautical Society.

### Historical Aircraft Society?

YOUR correspondent Mr. Gobby (November 8) refers to "apathy . . . when it comes to definite action" and refers, too, to the hypothetical British aeronautical community.

One way to overcome the apathy is by collective action, and the way to get this British aeronautical community—at least, those with its history at heart—together is by the formation of a society. Those interested in the history of aeronautics come from many walks of life, but they have no meeting place and no binding organization. There is a definite call for a historical aircraft society where papers of the calibre of Pritchard's biographies and Bruce's aeroplane histories could be aired. It need not have premises. An honorary secretariat should be able to do the work and a small subscription should weld together these people who are interested in this country's glorious past. Then, when a collective voice on a matter of history is called for, it will be there.

Walton-on-Thames. BELTANE.

### IN BRIEF

Mr. J. L. Dixon writes to say that he is compiling short histories of Nos. 7, 48, 87 and 256 Sqns., R.A.F., and would be grateful for material from ex-members. He adds that a few copies are still available of his *Brief History of No. 9 and No. 83 Squadrons*, and are available from him (price 2s each) at 5 St. Hilda Street, Bridlington, E. Yorks.

## THE INDUSTRY IN BRIEF

De Havilland Aircraft Proprietary, Ltd., Sydney, Australia, has appointed Mr. T. H. Dalton to take charge of the company's new office in Melbourne. He was formerly senior sales executive under the sales manager, Mr. R. Kingsford-Smith. Mr. Laurie Jones has been appointed to the business department to take Mr. Dalton's place and Mr. William D. Tulloch becomes public relations officer under the sales manager.

* * *

Mr. Sol Yager has been appointed managing director of the London Plywood and Timber Co., Ltd.

* * *

J. M. Steel and Co., Ltd., of Kern House, 36-38 Kingsway, London, W.C.2, and of Manchester and Birmingham, have opened new offices in Glasgow, at 144 St. Vincent Street, Glasgow, C.2.

* * *

We regret to record that Mr. B. H. Waller, chief purchasing officer of Hunting Percival Aircraft, Ltd., died on November 21 at the age of 59. He joined the then Percival Aircraft Co. in October 1938 as chief buyer, having previously been with Boulton and Paul, Ltd., since 1926.

* * *

Airtech, Ltd., have formed an engineering division, the company stating that in addition to offering a consultant design service for complete hydraulic and pneumatic systems it is manufacturing a range of these components for industry at home and overseas. Mr. P. J. Langdon, M.I.Ex., formerly with Bowden (Engineers), Ltd., and the aviation division of the Dunlop Rubber Co., Ltd., has been appointed sales manager of the new division.

* * *

Mr. J. R. Bradford, O.B.E., T.D., has been appointed public relations officer of the Bristol Aeroplane Co., Ltd. He joined the engine division of the Bristol Aeroplane Co. in 1953 as technical sales manager and has for the past year been directly responsible to Dr. S. G. Hooker, chief engineer and director of the engine company, for market research and other special duties. In his new capacity Mr. Bradford will be responsible to Mr. C. B. Bailey-Watson, public relations manager of the Bristol group.

With regret, we learn of the death (on November 20, at the age of 56) of Mr. Frank S. Allen, M.I.Prod.E., works director of E. K. Cole, Ltd., and a director of Ediswan-Ekco (Aust.) Pty., Ltd., Egen Electric, Ltd., Ekco Electronics, Ltd., and the National Ekco Radio and Engineering Co., Ltd. (India). He joined E. K. Cole, Ltd., in 1941 as assistant works manager.

* * *

Mr. Alan A. Holman has been appointed sales manager of Export Packing Service, Ltd., and will be in charge of the sales organization operating from 56 Kingsway, London, W.C.2. He has been manager of the company's outside branch for the past three years. Mr. R. T. Hill, sales director, has resigned his directorship to take up an appointment as director and general manager of the Dar-es-Salaam Motor Transport Co., Ltd.

### FORTHCOMING EVENTS

Dec. 6. Denham Flying Club; Opening Party, New Lounge Bar.
Dec. 11. Aircraft Recognition Society: December Forum.
Dec. 11. Kronfeld Club: "Life on the Planets," by Dr. A. E. Slater.
Dec. 12. R.Ae.S.: Main Lecture: "Ramjets," by R. P. Probert.
Dec. 14. Plymouth Aero Club: Christmas Party.
Dec. 17. R.Ae.S.: Section Lecture: "Comparison of Ducted Fan, By-pass and Straight Jet Engines," by Dr. S. G. Hooker, F.R.Ae.S.
Dec. 18. Kronfeld Club: Christmas Party.
Dec. 21. Lasham Gliding Centre: Christmas Party.
Dec. 21. Elstree Flying Club: Christmas Party.

R.Ae.S. Lectures (to Dec. 20):—

Dec. 9, *Halton*, Lecture by E. A. Tennant. Dec. 10, *Bristol*, "Aviation Finance," by G. E. Knight; *London Airport*, "Airline Economics," by S. Wheatcroft. Dec. 11, *Brough*, "Future Trends of Aircraft Propulsion Units," by A. Cdr. F. R. Banks; *Chester*, Lecturettes; *Christchurch*, "Fatigue Tests on the Bristol Britannia," by Dr. W. J. Strang; *Hatfield*, "The Domain of the Helicopter," by R. Hafner; *Reading*, "Investigation of Aircraft Accidents," by E. L. Ripley; *Southampton*, "The Weapon System Concept," by H. Davies; *Weybridge*, "The International Geophysical Year," by Prof. H. S. W. Massey. Dec. 12, *Cheltenham*, "Problems of Progressive Failure," by Sir Alfred Pugsley; *Glasgow*, "Fatigue and Fail-Safe in Aircraft Structures," by N. F. Harpur. Dec. 16, *Henlow*, "Artificial Satellites," by Dr. M. W. Ovenden. Dec. 17, *Boscombe Down*, "The Weapon System Concept," by H. Davies. Dec. 20, *Weybridge*, Annual Dance.

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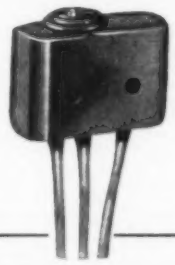

CATALOGUE LISTING 1SE1 *Sealed Sub Miniature.* This sealed version of the basic Sub Miniature Switch is immune to most environmental conditions. The Switch is embedded, with an epoxy resin, in an aluminium casing. Integral connecting leads are available in several lengths. Electrical Rating: as 11SM1-T. Contact Action: S.P.D.T. Data Sheet HB P96 gives full details.

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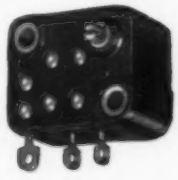

CATALOGUE LISTING V4-14 *Minimum Torque:* 0.140 OZ. INS. Honeywell Low Torque Rotary Action Switches are widely used in the coin chutes of vending machines—to initiate the vending process. These switches are also used in air flow failure devices and in textile machines as thread-break detectors. The torque is usually applied to a wire lever actuator. Electrical rating: 5A up to 250V A.C. Contact Action: S.P.D.T. Data Sheet 46c gives full details.

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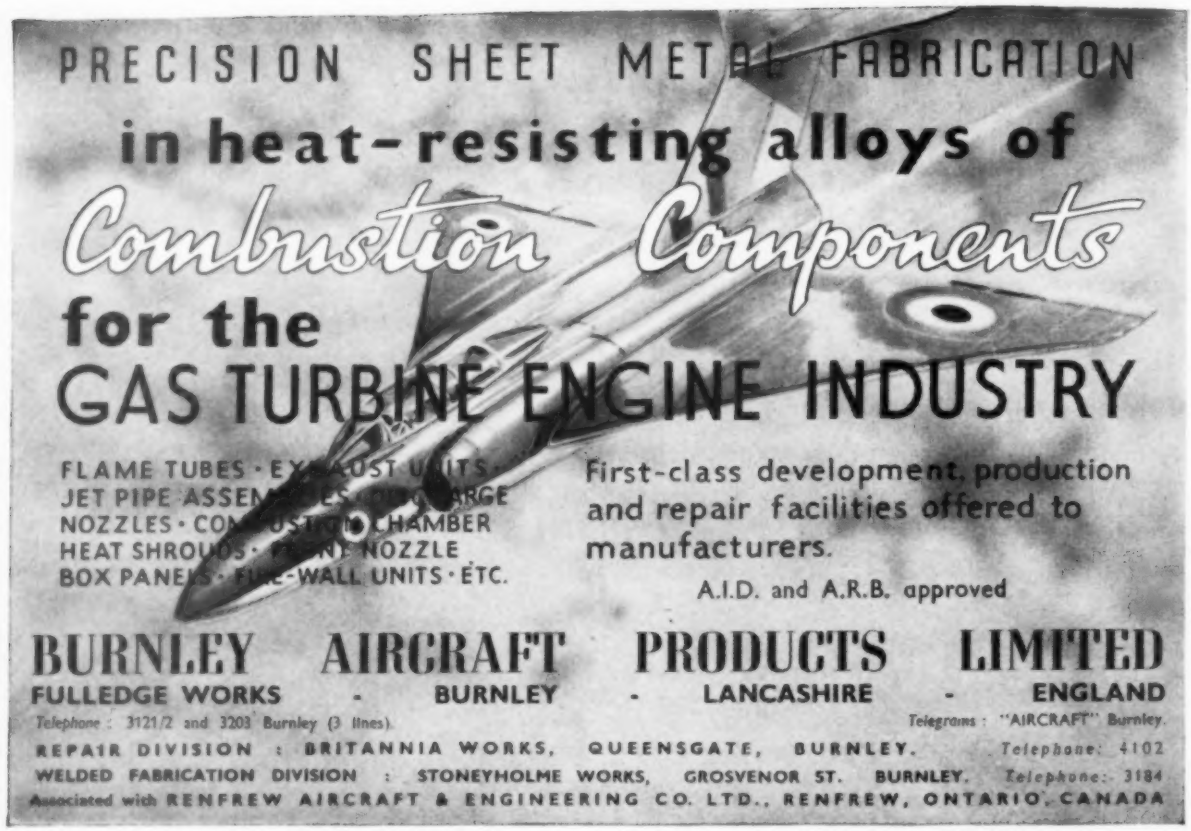
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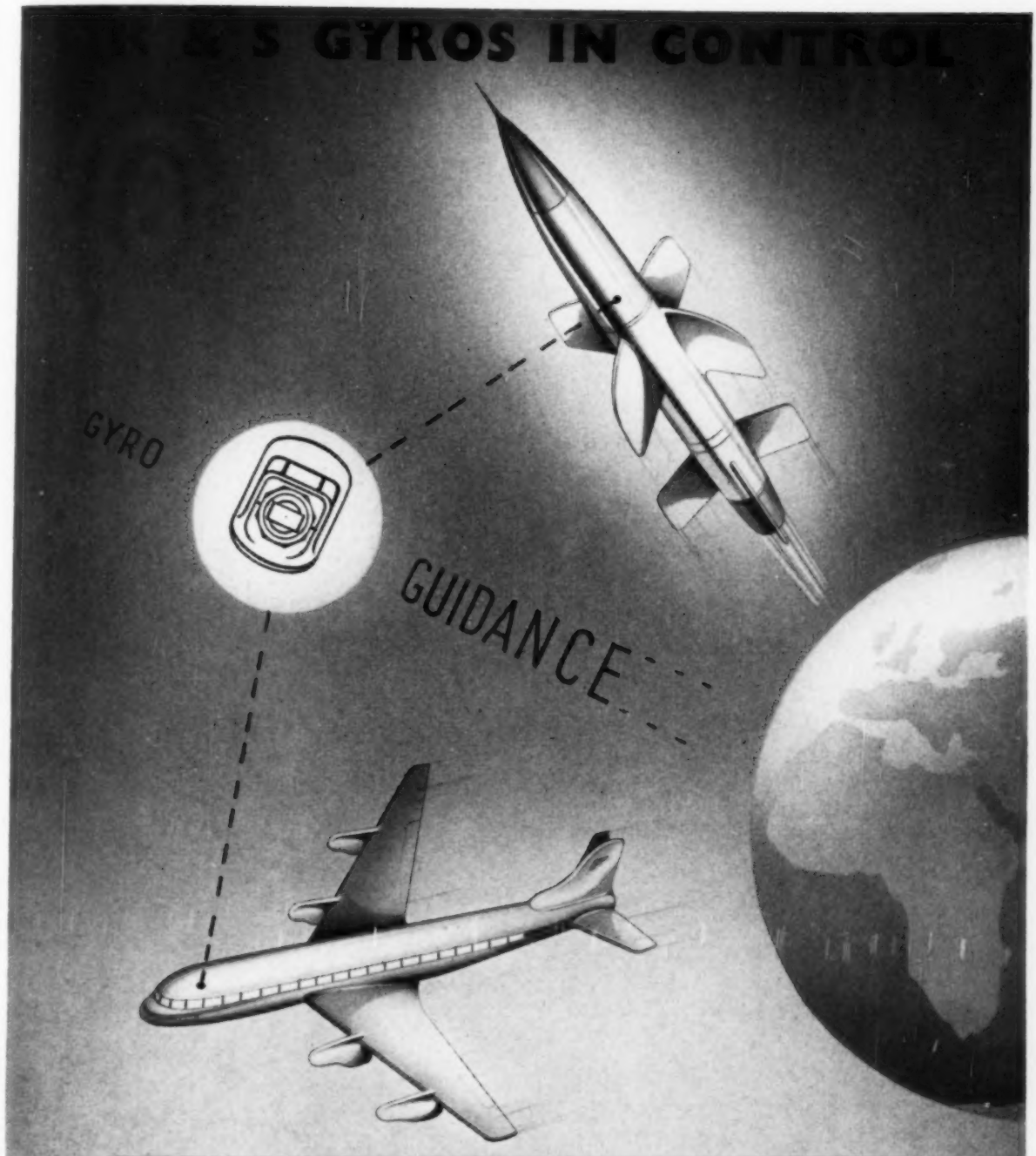


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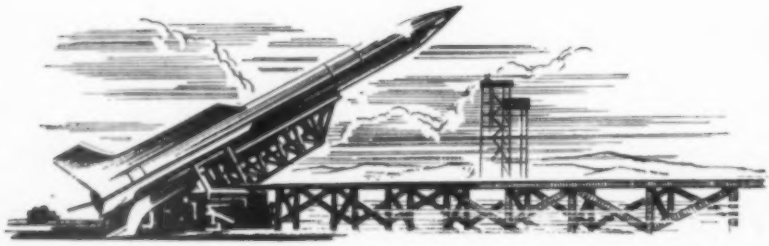

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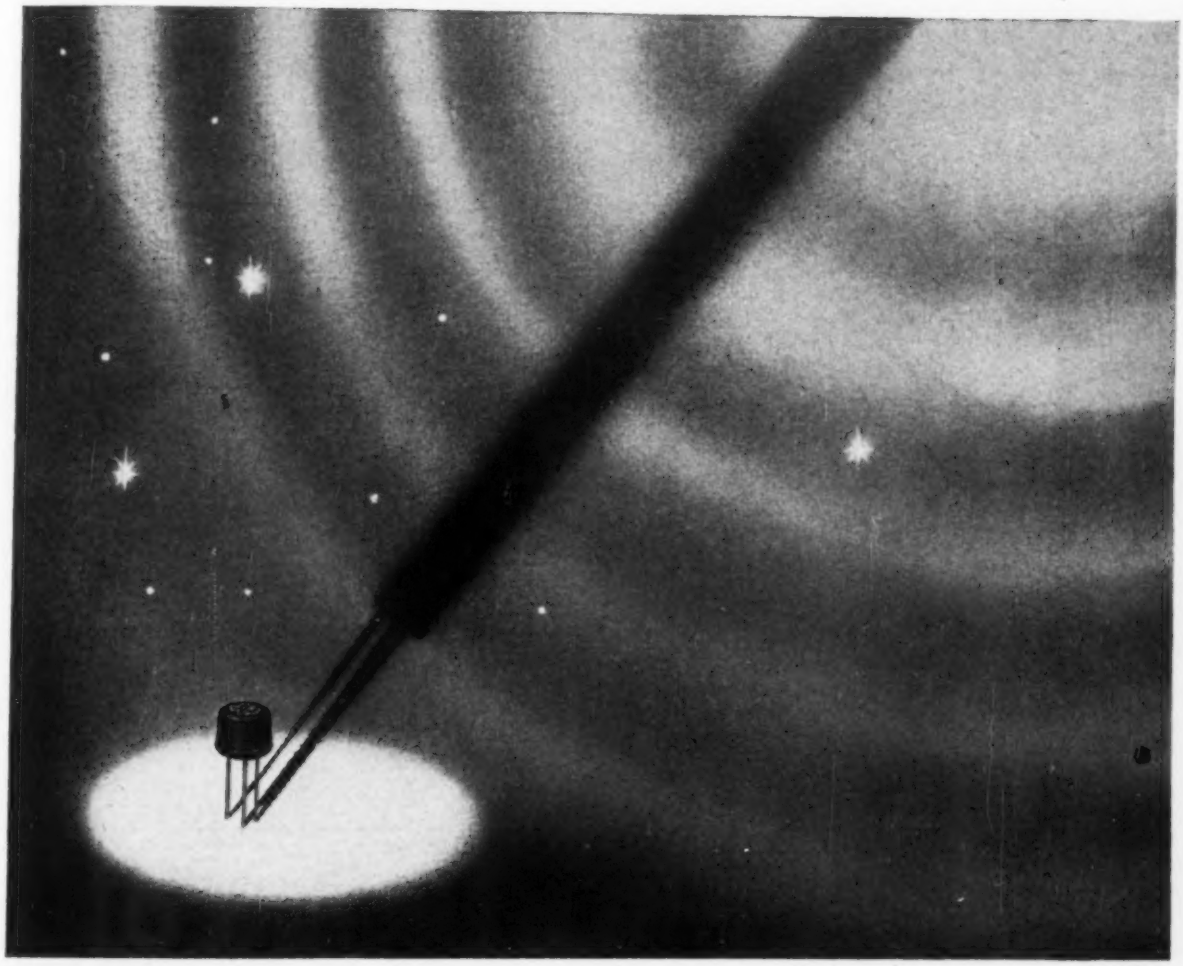

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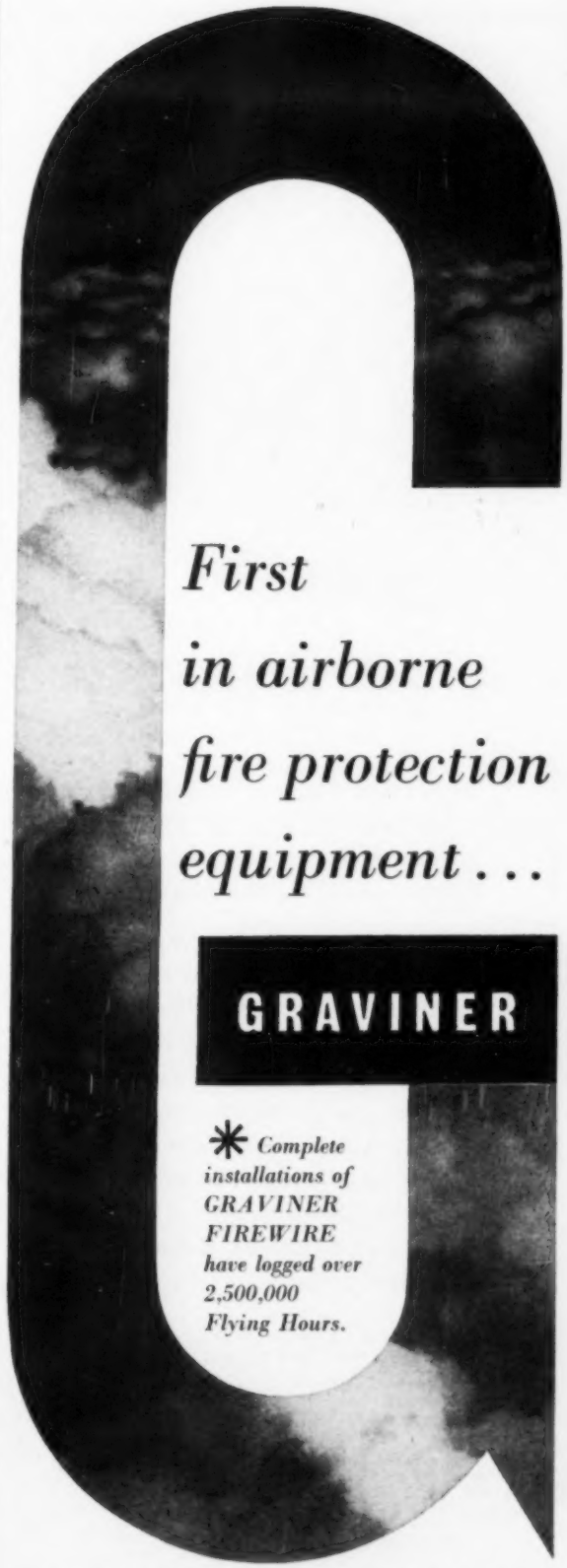

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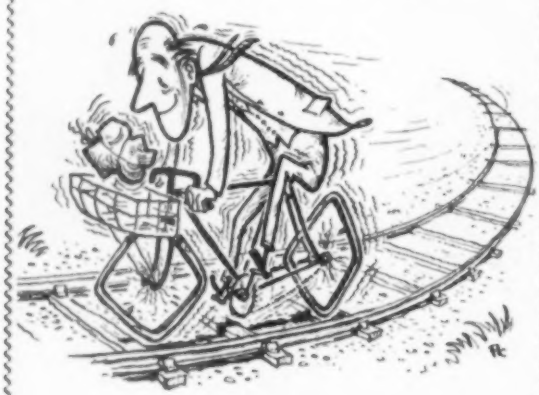

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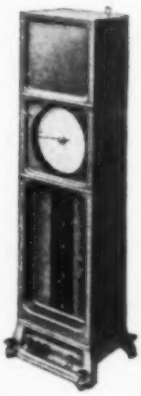

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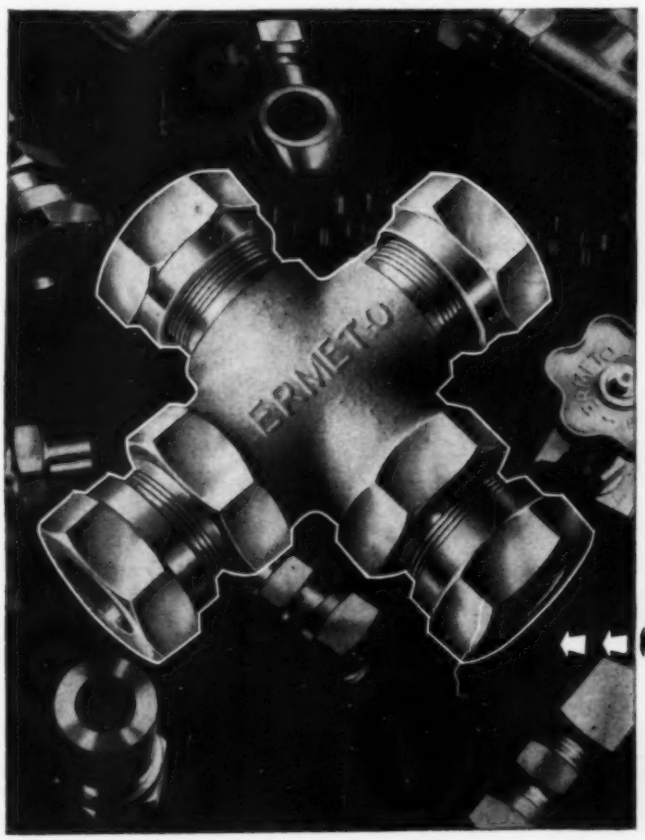


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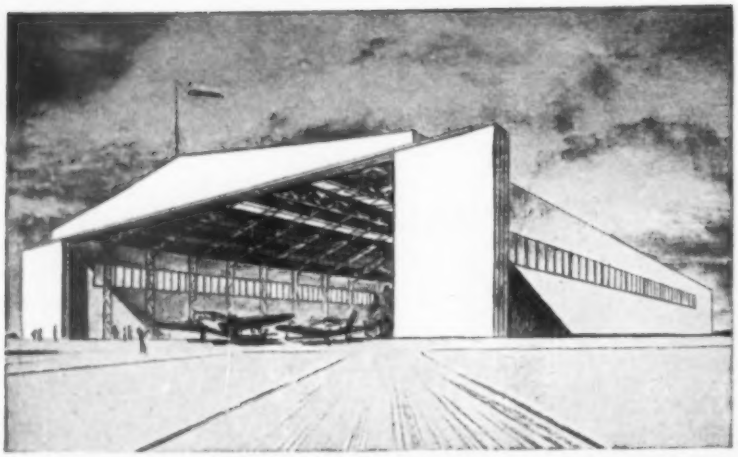

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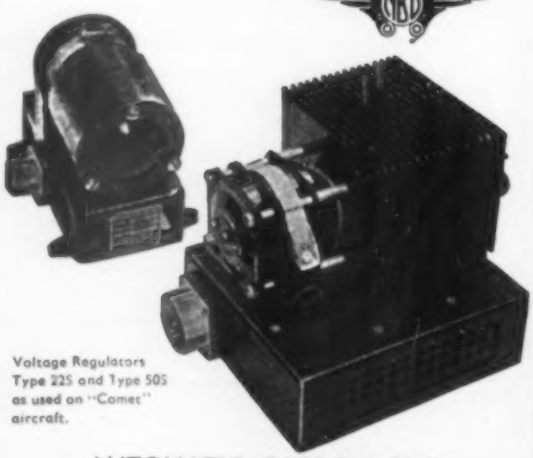

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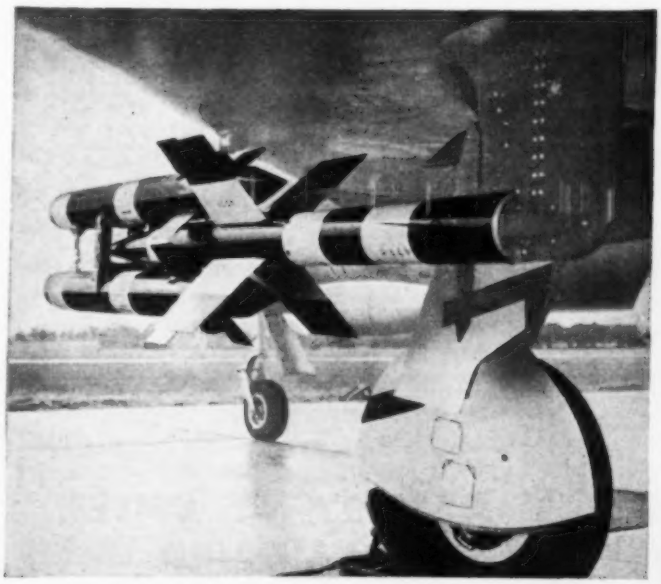

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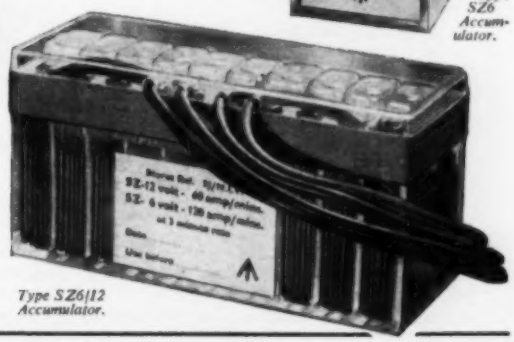

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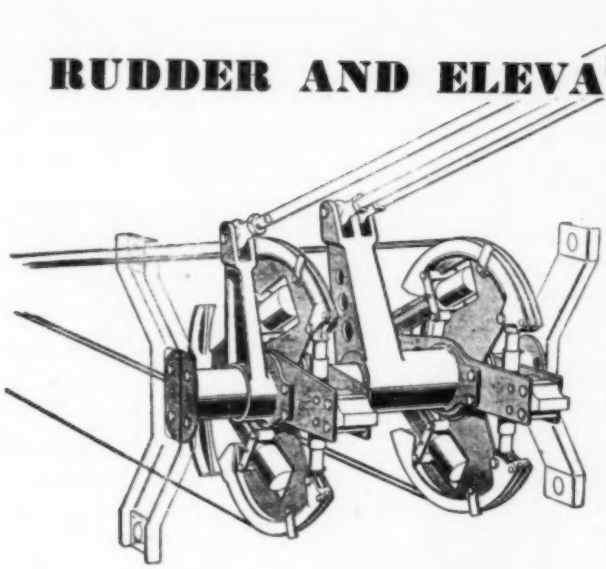

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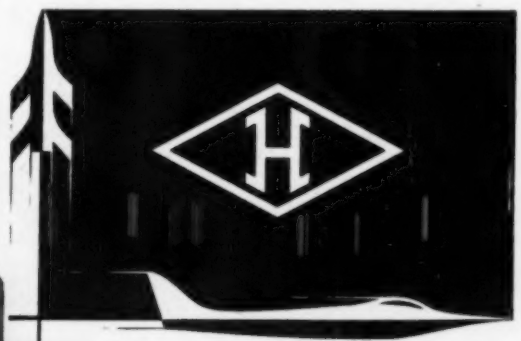

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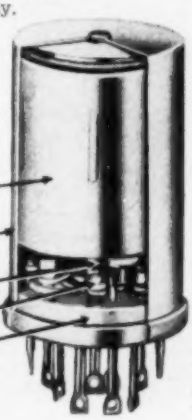


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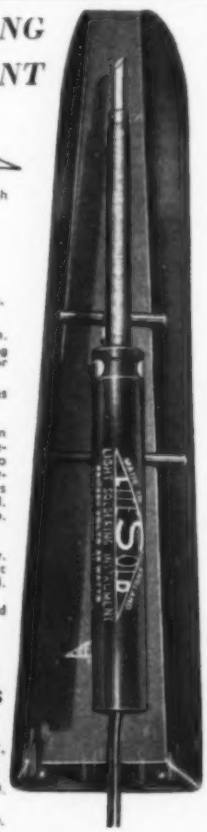

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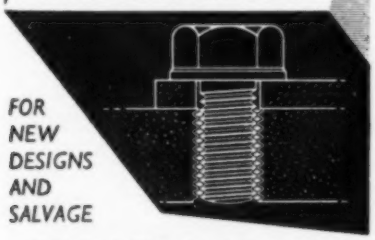

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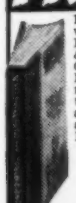

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THE AIR TRANSPORT ADVISORY COUNCIL give notice that they have received the undermentioned applications to operate scheduled air services:

APPLICATION No. 1558 from British European Airways Corporation of Keyline House, Ruislip, Middlesex, for an All Freight Service with DC3 and Viscount aircraft between Southampton and Jersey at a frequency in accordance with traffic demand for a period 10 years from date of approval.

FROM Derby Aviation, Ltd., of Derby Airport, Burnaston, Derby: Application No. 143/7 for an amendment to the terms of approval of the Seasonal U.K. Internal Service which they are authorized to operate with DH.89, Dakota and Marathon aircraft on the route Nottingham (Tollerton, and/or Derby (Burnaston)-Wolverhampton (optional)-Birmingham (Elmdon) or Southampton (Eastleigh) (technical stops)-Jersey, until 30th September, 1959, and which they have previously applied to amend so as to permit the operation of four return flights weekly between Mondays and Thursdays and 14 return flights weekly between Fridays and Sundays from 1st March to 31st October each year with an optional traffic stop at Guernsey and integration with their U.K. Internal Service on the route Oxford (Kidlington)-Southampton (Eastleigh) (technical)-Jersey, so as now to permit the inclusion of an optional traffic stop at Northampton (Sywell Airport) initially on six services weekly increasing later according to traffic demand.

APPLICATION No. 658/2 for an amendment to the terms of approval of the U.K. Internal Service which they are authorized to operate with Dakota and Marathon aircraft on the route Birmingham (Elmdon (optional)-Derby-Carlisle (Crosby) (optional)-Edinburgh (Turnhouse) (optional)-Glasgow (Renfrew) until 21st February, 1963, at a frequency of one return flight daily on Mondays, Tuesdays, Wednesdays, Thursdays and Fridays only, so as to permit the operation of one return flight daily throughout the week.

THESE applications will be considered by the Council under the Terms of Reference issued to them by the Minister of Civil Aviation on 30th July, 1952. Any representations or objections with regard to these applications must be made in writing stating the reasons and must reach the Council within 14 days of the date of this advertisement, addressed to the Secretary, Air Transport Advisory Council, 3 Dean's Yard, London, S.W.1, from whom further details of the applications may be obtained. When an objection is made to an application by another air transport company on the grounds that they are applying to operate the route or part of route in question, their application, if not already submitted to the Council, should reach them within the period allowed for the making of representations or objections. [7357


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## PATENTS

THE proprietor of British Patent No. 644478 entitled Improvements in Rotor Blade Airfoils, offers same for license or otherwise to ensure its practical working in Great Britain. Inquiries to Singer, Stern & Carlberg, Chrysler Building, New York 17, N.Y., U.S.A. [7365

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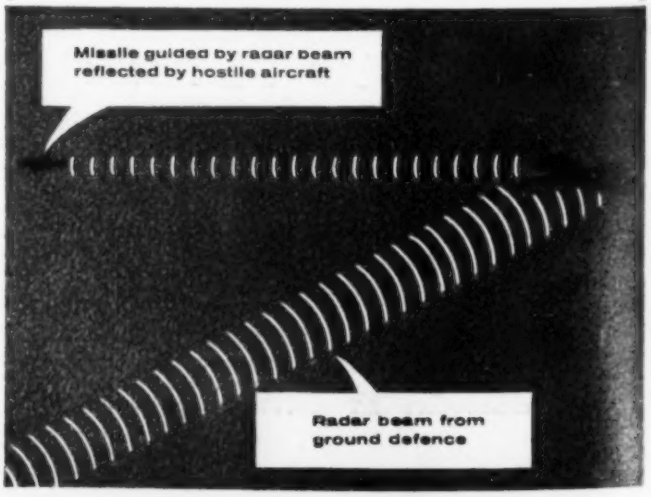
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